



Bulgarian Soil Science Society

BULGARIAN JOURNAL OF SOIL SCIENCE®

2017

Volume 2

Issue 1

e-ISSN: 2367-9121 ISSN: 2534-8787

BULGARIAN JOURNAL OF SOIL SCIENCE®

(Peer Reviewed Open Access Journal)

Published by Bulgarian Soil Science Society

Editor-in-Chief
Prof. Metodi Teoharov

Executive-Editor
Prof. Irena Atanassova

Editorial Board

Prof. Rattan Lal
Prof. Rainer Horn
Prof. Evgeny Shein
Prof. Pandi Zdruli
Prof. Milan Mesič
Prof. Dimitranka Stoycheva
Prof. Zornitza Popova
Prof. Radka Donkova

Prof. Ludmila Malinova
Assoc. prof. Zdravka Petkova
Assoc. prof. Rada Povova
Assoc. prof. Milena Kercheva
Assoc. prof. Neli Gadzhalska
Assoc. prof. Toma Shishkov
Assoc. prof. Katerina Doneva

Technical Editor - Pre-print - Web Support
Asst. prof. Biser Hristov



The Executive Board of the Bulgarian Soil Science Society has decided to begin publishing Bulgarian Journal of Soil Science in relation to the International Year of Soils 2015, as a web-based, free, and open-access international scientific journal. The Editorial Advisory Board consists of European researchers and specialists in the field of soil science and other related sciences.

We are confident that Bulgarian Journal of Soil Science will unite the research of specialists and scientists in soil science from all over the world, as well as help them in the processes of their scientific integration. Bulgarian Journal of Soil Science is an international open-access, web-based scientific journal dedicated to the publication and discussion of high-quality research in the field of soil sciences. Bulgarian Journal of Soil Science publishes scientific research that contributes to the understanding of soil and its interaction with humans and the entire Earth system. The scope of the journal includes all topics relevant to the study of soil science as a discipline. The journal publishes original papers in specific topic sections on global and regional, theoretical and experimental studies concerning the problems of genesis, geography, physics, chemistry, biology, fertility, management, conservation, and remediation of soils.

Author instructions can be found on the official webpage and in the journal.

<http://www.bsss.bg/Journal.html> e-mail: journal@bsss.bg e-ISSN: 2367-9121 ISSN: 2534-8787

BULGARIAN JOURNAL OF SOIL SCIENCE®

CONTENTS

VOLUME : 2

ISSUE : 1

PAGES : 1 - 86

	To the Readers <i>Metodi Teoharov</i>	3
	<i>History of Soil Science</i>	
1	Soil Science of Past, Present and Future <i>Metodi Teoharov</i>	4 - 17
	<i>Tropical Soil Science</i>	
2	Tropical soils: Importance, Research and Management <i>Ognyan Kostov</i>	18 - 31
	<i>Soil Genesis and Diagnostics</i>	
3	Characteristics of Rendzinas in the Ludogorie Region <i>Vladimir Ilinkin, Simeon Bogdanov, Antonia Goleva</i>	32 - 41
	<i>Agrochemistry and Soil Fertility</i>	
4	Forms and Distribution of Potassium in Red Laterite Soils of Patigi in North Central Nigeria <i>A.D Idris, J.O. Olaniyan, K.O Affinnih, O.N Ajala</i>	42 - 52
	<i>Soil Amelioration and Sustainable Agriculture</i>	
5	Utilization of Biochar in Improving Yield of Wheat in Bangladesh <i>Md. Toufiq Iqbal</i>	53 - 74
	<i>Science and Education</i>	
6	Sustainable Development in Education of Horticulture <i>Nidal Shaban, <u>Sergei Bistrichanov</u>, Eman Kadum, Miroslav Tityanov</i>	75 - 82
	Instructions for Authors	83 - 86

To the Readers

Editor-in-Chief

Prof. Metodi Teoharov

Dear readers of Bulgarian Journal of Soil Science,

Dear colleagues,

It has been one year since Bulgarian Journal of Soil Science has been issued as an organ of the Bulgarian Soil Science Society. Its Editorial Board includes prominent foreign and Bulgarian scientists with proven contribution to science and practice. Having in mind the fact that this is an international journal the Editorial Board sets high requirements to the authors of articles, which are strictly fulfilled in the process of preparation of the papers for publishing. I would like to express my extreme gratitude to all authors for the good cooperation and the responsibility they have taken in our collaboration.

In 2016 Bulgarian Journal of Soil Science included topical rubrics, related to the genesis, geography, diagnostics, classification, land evaluation and categorization of soils and land resources as well as to their sustainable use and conservation, the agro chemical and agro ecological servicing, increasing soil fertility, organic and biological agriculture, agronomical aptitude of agricultural crops, biodiversity, eco-system services, pollution and environmental conservation

Bulgarian Journal of Soil Science is a generator and propagator of modern knowledge and innovation solutions, which are of high necessity for the management of natural resources and the modern development of economy. The journal is a tribune and an appeal for more common sense and thought, for harmony, productivity, peace and prosperity on the Earth.

- Common sense and thought in order to control the processes of anthropogenic and technogenic degradation of soil and land resources.
- Harmony and productivity in order to preserve and pass on these resources to the future generations in the way we inherited them from our ancestors.
- Peace and prosperity so that there is bread for everyone and we stop accumulating waste, poisons, plumbum and human blood in soil.

Dear Authors, Colleagues and Readers,

Let your scientific ideas be the reply to this appeal so that the land that feeds and purifies us, remain our common home in the future! Let us continue working together and affirm the soil science in every corner of the globe!

Prof. Metodi Teoharov, PhD

Editor-In-Chief of Bulgarian Journal of Soil Science



Soil Science – Science of Past, Present and Future

Metodi Teoharov

President of Bulgarian Soil Science Society

1331 Sofia, 7 Shosse Bankya str.

Corresponding Author: Metodi Teoharov, e-mail: mteoharov@abv.com



Abstract

The present study includes a detailed analysis on the past, present and future of the soil science in the Bulgaria and over the world. Soil science entered in the cycle of scientific discipline serving practice when in 1883 the famous Russian scientist V.V.Dokuchaev established regularities of soil formation. Since then it has emerged as an important branch of biological science and it has become a science of undoubtedly great for public importance. There are different periods how it was developed in Bulgaria and in the rest of the world. In third period is examined Vernadski's concept of the Noosphere and relationship with soil science and how „the thoughtful layer of the planet” can repairs the consequences of the Technosphere and Anthropocentris.

Key words: Soil science, development, periods, world schools, FAO-classification, WRBSR, Noosphere, Technosphere and Anthropocentris.

The Beginning

Dokuchaev – Founder of the World Genetic Soil Science



*V.V. Dokuchaev
1846 - 1903*

The science of soils was founded under the name pedology by the world-famous Russian soil scientist V.V. Dokuchaev 133 years ago - after he wrote the major work “Russian Chernozem” in 1883. In it he proved the genetic origin of soils and the regularities of their distribution. Dokuchaev wrote that “the soils are the result of extremely complicated interaction of the local climate, the plant and animal organisms, the composition and structure of the parent rock and in the end the age of the country”. His scientific ideas were very fast supported first in Europe and then in America. Thus the end of the 19th century and the beginning of the 20th century became an active period for the soil scientists in a number of countries. The first teams of scientists and national schools were created and



N. Poushkarov
1874 - 1943

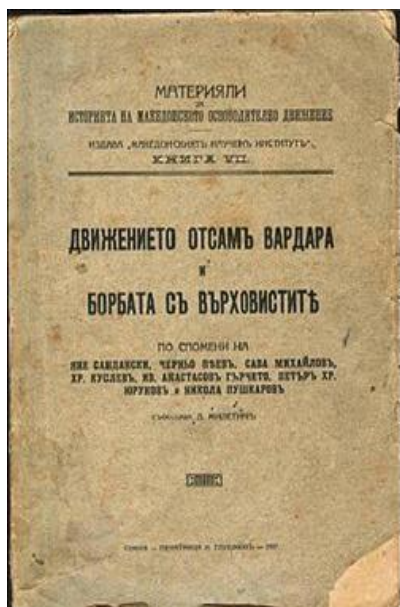
Revolutionary Committee of Skopje. His love to geology and soil science made him collect rock samples in his rucksack while he was hiking around the mountains, carrying bombs and bullets on him (Teoharov, 2011). Historical archives show that his revolutionary, cultural, educational, pedagogical, researching and publishing activities were really substantial. The top of his deals was his scientific works, in which he consigned a lot of labour, ideas, heart and talent, which are important for all generations to come.

they began to investigate the soil resources of their countries. Dokuchaev's study was later accepted by scientists from all over the world.

Pushkarov – Founder of Bulgarian Soil Science

In our country the founder of soil science was the great public figure, patriot and enlightener Nikola Pushkarov. Before writing his fundamental work "Formation of Soils" in 1909 and creating a soil science (agro-geological) section to the State Agriculture Station in Sofia in 1911, his life was linked with that of the so called Macedonian Levski – Gotse Delchev and the struggle for liberation of the Bulgarians in Macedonia, where he was a teacher and publisher of the Liberation newspaper, leader of a revolutionary unit and Chairman of the

Development of Soil Science in the First Half of the 20th Century in Europe and America



At the time when Puskarov was fighting for unification of the land of Bulgaria, a successful attempt for soil-grouping on a genetic principle was made in Germany. Nevertheless, the agro-geological soil science, which regards the soil as a purely geological formation was developed as an alternative of the genetic soil science. The soil scientists in France accepted a lot of the Dokuchaev's concepts, terms and ideas and published their first national soil map in 1838. In 1927 in America the first taxonomic grouping of the soils from Marbut was also made and it corresponded to the genetic soil types, introduced by Dokuchaev. The new doctrine quickly brought scientists in Europe together and soil science was acknowledged as an agronomical science. Scientists began organizing and conducting a number of scientific conferences and congresses in the countries of advanced economies and scientific activities.

TABLE 21.2 : Marbut's system of soil classification

Soil order	Sub-order	Soil group
I. ZONAL SOIL	1. Arctic pedalfer 2. Temperate pealfers	1. Tundra soil 1. Podsol soils 2. Brown and grey podsol soils
(a) Pedalfers	3. Tropical pedalfer	1. Yellow and red podsol soils 2. Laterite soils
(b) Pedocals	4. Transition pedalfer 1. Temperate pedocals	1. Degraded chernozem soils 1. Chernozem soils 2. Chestnut soil
II. INTRAZONAL SOIL	2. Tropical pedocals	1. Brown soils 2. Desert soils
	1. Halomorphic 2. Hydromorphic	1. Saline and alkaline soils 1. Bog or marsh soil 2. Meadow soils
III. AZONAL SOIL	3. Calomorphie Or Calcimorphie	1. Rendizine soils 2. Brown forest soils 1. Lithosols 2. Regosols (dry sands) 1. Alluvial soils

First International Conferences and Congresses

An international contact of soil scientists was first established in 1908, when Russian, Hungarian and Rumanian scientists got together and planned the organization of joint scientific excursions. They decided to hold the first international forum in Hungary. In 1909 the First International Agronomical Pedology Conference was held in Budapest. In 1910 in Stockholm at the Second International Pedology Conference a decision was made to publish an international soil science journal which was released in 1911. The First World War brought the international scientific activity to a stop and the Third International Pedology Conference was not held until 1922 in Prague, where 14 countries participated, including the USA. At this conference the soil science broke away from the geological trend and fully accepted Dokuchaev's genetic approach to soil studies. After a decision made by a commission of soil scientists in Zurich in 1923, at the Forth International Agronomical Conference in Rome, which turned into a Congress (1924), important decisions were made for the further development of soil science. The name pedology was abandoned and replaced by "soil science" (Stranski, 1946). The conference was attended by 340 delegates from different countries.



Agronomical Pedology Conference held in Budapest 1911.

Foundation of the International Association of Soil Scientists

At the same time The Forth Congress founded the International Association of Soil Scientists, which is a predecessor of today's International Union of Soil Scientists. Until the Second World the Association held three congresses – in Washington (1927), where the first American soil classification was adopted under the presidency of the Russian soil scientist Glinka; in Leningrad (1930), where the Russian soil scientists suggested the sequential improved classification of the methods of soil research and some other organizational problems, as Association already included 1228 soil scientists. On the eve of the Second World War the International Association interrupted the scientific progress again.

How Bulgarian Soil Science Had Developed until That Period



*Academician Georgi Bonchev
1866 - 1955*

Bulgarian Soil Science School owes its development to a lot of talented soil scientists being influenced by leading national and international schools.

Our first soil scientist Nikola Pushkarov was a follower of the German school as he specialized with the German professor Raman for a year and a half. Raman was the creator of the first soil classification in Germany. Pushkarov adopted the ideas and contents of the genetic approach for soil research but until 1922 he formed the titles of his works by agro-geological terminology. (Soil-Geological Description of the Sofia Field (1913), Soil-Geological Sketch of the Pirdop Administrative District (1920). Naturally Pushkarov did not only experience the influence of the leading schools, but he was also influenced by his Bulgarian mentor – the famous geologist

Academician Georgi Bonchev. Furthermore Pushkarov himself was a geologist, too. Nevertheless, it is seen in his works that in ideas and contents he was a convinced follower of Dokuchaev's genetic soil science, which makes him a scientist of world recognition and significance.

Pushkarov's Contribution to Soil Science



House of N. Poushkarov

Pushkarov developed the first program for large-scale soil research in Bulgaria and also the first soil classification and land evaluation by types. He revealed the regularities and geographical distribution of soils; he applied differentiated approach to the agronomical suitability of soils and the increase of their

fertility. Pushkarov also created the first National Soil Map (1931) in Scale 1:500000 in Bulgarian and German language at a time when even most developed countries did not have one. The map, which he published at his own



Chernozem profile

expense and which he had to pay for all his life, is a great achievement not only for our national science but also for the European one, as it was later used by Shtreme (1935) for the design of the first European Soil Map. It must definitely be pointed out that the period 1911-1943 (1943 being the year of Pushkarov death) is evaluated by world-famous scientists as a very successful stage for Bulgarian soil science.

Soil Science in the Second Half of the XXth Century

After the Second World War the soil science in the world developed at a greater speed according to the status of the economies of the different countries. Although the world was separated into two political systems the soil scientists were united in the design and application of science-based methods and decisions, aiming at rational use and conservation of soil resources and solving the problem of supplies. Proofs of that fact are the constant business contacts and the development and execution of joint scientific projects and programs.

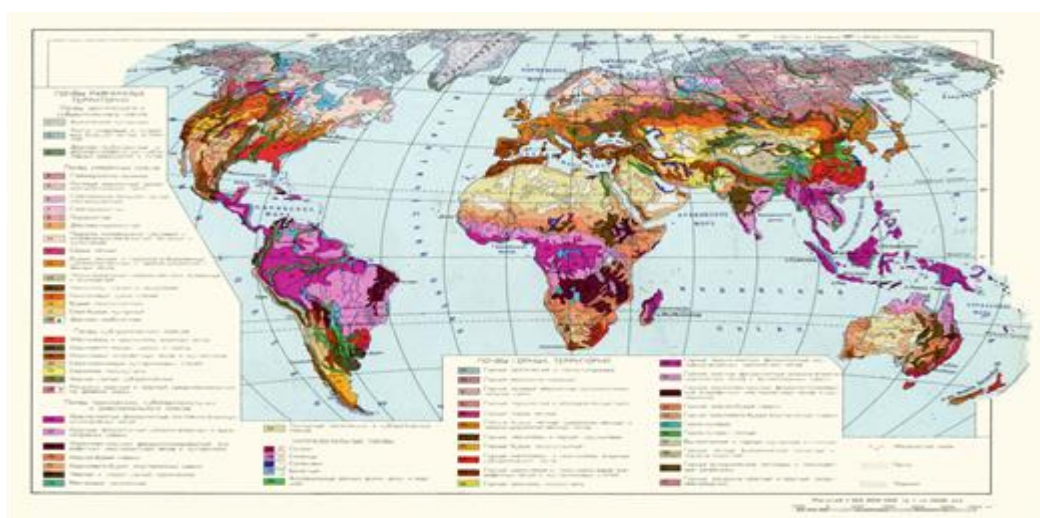


Soil Science – The base of modern agriculture

The most important thing is the appearance of the new concept of the noosphere and its influence on reasonable use of the natural resources, including the soils, which reflects the unobserved progress of the soil science in Europe and in the world. Dozens of international conferences and 20 congresses were held in different cities of the world. Their technical achievements were used in the adoption of a lot of inter-government, inter-state and international conventions and agreements for conservation of the soil and land resources and the biodiversity of the planet.

First Soil Map of the World

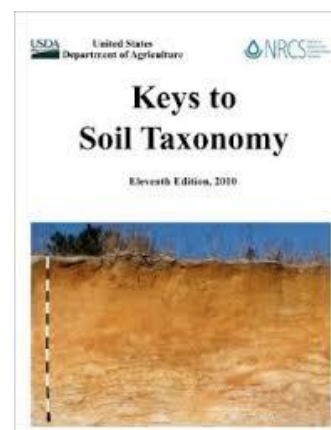
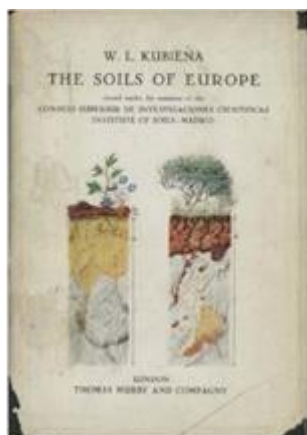
The First World Soil Map was published in the Soviet Union in 1954 and it was successively improved in 1955 and 1974. It was used for the development of the next two maps of soil grouping of FAO. In more recent times the scientists in Europe have developed the European and World Charter of Soil. At this moment soil scientists are conducting a European petition (People 4 Soil) for adoption European Charter. The UN declared 5th December as a World Day of Soil and 2015 as an International Year of Soil, which is a great achievement for the UN, accomplished thanks to the enormous work of the national societies and the International Council of Soil Science.



Soil Map of the world

The Leading Role of the World Schools

The soil systematic and classifications of Shtreme (1950) and of Kubiena (1950) include plenty of interesting and valuable research of the genesis, composition, properties and geographic distribution of European soils. The French soil scientists under the leadership of Prof. Duchaufour (1965) and Prof. Aubert (1967) successively improved the soil systematics and later, in 1988 they published the French Referential Base of Soils, which comprised the latest achievements of Russian, European and world soil science. In 1977 under the methodical leadership of Academician Kovda and Academician Gerasimov the new and improved Russian classification was published. In the USA Prof. Guy Smith and Prof. Arnold continued to improve the soil taxonomy and it underwent several editions (Soil Taxonomy, 1990). After 1990 Prof. Arnold, who is a respected scientist in Southeast Europe, was admitted as member of the Editorial board of the international Russian journal.



Soil Science. Soil scientists from leading schools (including Bulgaria) conduct research of soils on all continents.

FAO Classification – Great World Scientific Achievement



The results of the conducted research throughout the world are the basis of the successively designed and improved world soil maps and the grouping of soils in so called FAO Legend (1964). In this first version of the FAO soil system 37 soil groups are includes, 24 of which were taken from the Russian classification. This version underwent several editions until the World Referential Base of Soil Resources was developed and after several successive congresses it was

adopted and published in 1998 by the XVI congress in Montpellier, France. New two actualized versions are published in 2006 and 2014.

Bulgarian Soil Scientists – Co-organizers and Participants in the Development of the World Referential Base of Soils



Academician Ivan Stranski
1886 - 1959

Bulgarian soil scientists had a serious contribution in its development. They had the chance and opportunity to unite the efforts of the international soil science community by a decision of the FAO, UNESCO, UNEP and the International Organization of Soil Scientists. FAO authorized Prof. Fridland as their representative and coordinator to organize workshops in Bulgaria. Thus the basic principal concepts of the FAO classification were set and developed at three successive workshops in Pushkarov Institute in 1980, 1981, and 1983. To deserve such trust Pushkarov Institute under the leadership of



Prof. Ivan Garbucheve turned into a research and educational centre of rich material and technical base and hundreds of talented scientists – both Bulgarian and foreign, so Bulgarian soil science was recognized as one of the best developed in the world. It was working in favor of the national and world soil science and it was a basic factor for the progress in agriculture. So as to reach this appreciation a great research activity was conducted in Bulgaria and dozens of international science events were held here. Bulgarian soil scientists had a very successful cooperation with Russian, French, German, Dutch, Czech, Slovakian, Hungarian, Polish and Belgian soil scientists.

Soil Expedition by prof. V. Koinov, prof. N. Ninov, prof. G. Gurov, prof. Hr. Trashliev

Bulgarian-Soviet Soil Expedition. Nationally Important Scientific Achievements of Bulgarian Soil Science



Academician
I. P. Gerasimov
1905 - 1985

In 1947 a Bulgarian-Soviet soil expedition under the leadership of the academicians I.N.Antipov-Karataev and I.P.Gerasimov was conducted. Modern diagnostics and classification of soils was developed and “Soils in Bulgaria” (1960) - the first modern and comprehensive academic work in the area of soil science was published. It played a significant role in the science-based agro-productive zoning of agricultural crops in Bulgaria.

The country was covered by large-scale soil research in Scale 1: 25000 и 1:10000. Soil-climatic and agro-chemical characteristics with cartograms and specific technological solutions for agriculture were developed for every land area in the country. New methods for categorization of agricultural land were adopted and land evaluation of the total soil and land resource was performed. The first agro-ecological map was created and the first agricultural zoning of Bulgaria was done. Two national maps in Scale 1:500000 и 1:200000 (Tanov, 1956), (Koinov, et al., 1968) were designed. Three versions of the Bulgarian classification were successively updated by Koinov, et al. (1964), Yolevski, et al. (1983) and Penkov, et al. (1992). Harmonization of the diagnostics and correlations of Bulgarian soils with leading international and world



Academician
Antipov – Karataev
1888 - 1965



Soils of Bulgaria

classifications was achieved (Koinov, et al., 1987; Boyadzhiev, 1994; Ninov, 1998; Teoharov, 2004).

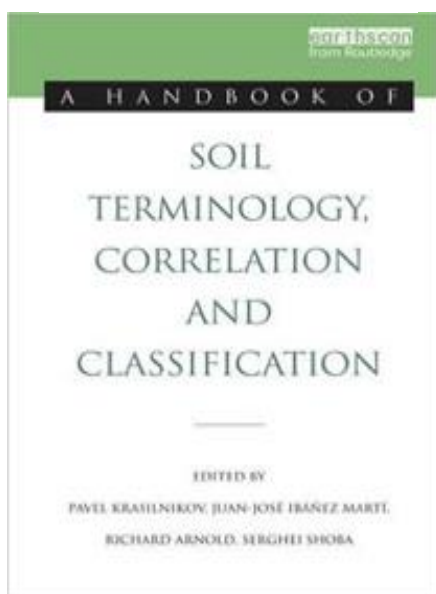
The Present Times

Bulgarian-American Soil Expeditions and Participation of the Soil Scientists in the European Research Area



Prof. Richard Arnold

After the changes in the political system at the beginning of the 1990's the soil science in Bulgaria continued to use the world experience. There were two Bulgarian-American expeditions in South and North Bulgaria, the results of which were included in the world database. The first decade of the 21-st emerged as an active period, in which Bulgarian research scientists performed important scientific projects for Bulgaria and Europe in cooperation with European scientists and scientific teams in the area of unification of the research methods, the diagnostics and classification of soils, soil cartography, the geographic-information systems, degradation and contamination of soils and waters, bio-methods, the use of biogas, etc.



However, in the pursuit of harmonization of our ideas, projects and scientific methods with the European ones, a number of important national tasks, related to the fundamental and applied soil science and mostly the agro-ecological and agro-chemical servicing was neglected and not restored until 2008-2011. (Teoharov, et al., 2009, 2010). Quarter century Bulgarian soil classification is not updated. The state institutions also take responsibility for this underestimation and neglect as they pulled out a great part of the scientific potential and the scientific database of Pushkarov Institute and subjected to an experiment the implementation and innovative activities and later they faced the necessity of closing the previously set up for that particular purpose state organizations.

The rich scientific information accumulated by 1998 is constantly used under the current economic conditions but it must necessarily be updated. Why? Over the last three decades the ecological and agrarian culture has been developing in some aspects and degrading in others. Soils have been degrading, too.

Soils in Bulgaria and world - under Anthropogenic and Technogenic Pressure



Soils and land in areas of intensive agricultural and industrial production are mostly subjected to a great anthropogenic and technogenic pressure – a phenomenon, which is characteristic not only of Bulgaria but of the entire world. That is why in Bulgarian and in FAO classifications new soils appeared – Anthropogenic and Technogenic ones (WRBSB, 2006). A new era, called Anthropocentris, was introduced into the geological science. These



are serious indicators above all of Man's influence on the changes in soils and land, which include the reduction of the organic carbon on the planet, acceleration of the processes of dehumification, contamination and degradation of soils, disturbance of their natural status, structure, properties, qualities and nutrition balance. The erroneous systems of cultivation, ameliorations and plant protection methods accelerate those unfavorable processes.

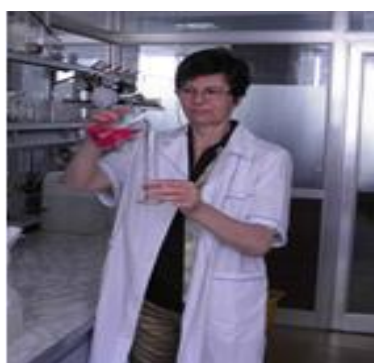
Technogenic profile

Necessity of the Application of Agro-chemical and Agro-ecological Control



ISSAPP "N. Poushkarov"

The necessity of restoration and application of the agro-chemical and agro-ecological control requiring state support is more than obligatory because of the fact that traditional principles and norms of the agricultural production and the use of soil resources are broken.



The state must trust the soil science, which, in spite of the crisis it is in, still has the necessary potential to suggest modern methods and to limit the unfavorable trends. To that purpose the scientific and above all managerial and state subject do need a new way of thinking, new ideas and a new approach for application of the scientific achievements.

Agro-chemical and agroecological analysis – chemist R. Sechkova

The Future

Academician Vernadski's Concept of the Noosphere and Its Relationship with Soil Science



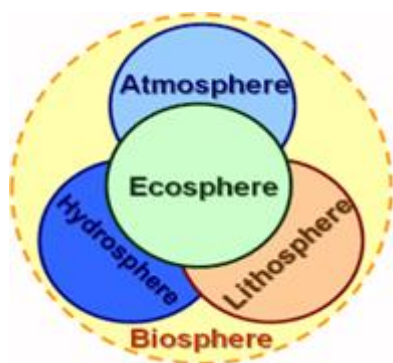
Academician V. Vernadski
1863 - 1945

The future belongs to the study of the noosphere, which is unbreakably linked with soil science. The creation of this new science by Acad. Vernadski, who is a follower and student of Dokuchaev's and the application of the noogenetic approach of management of every natural and human resource lies at the basis of every useful decision. This is a study for the sense and conscience of Man and also for his well-designed, reasonable and conscious ideas and actions and also of his badly-designed, unreasonable, thoughtless and destructive ones, which change the biosphere, mankind and the Earth. According to Vernadski "we live in an unprecedentedly new geological epoch, the man with his work and his conscious attitude to life remodels the Earth cover, the geological area of life, the biosphere. He turns the Earth into a new geological status. Through his labour and conscience the biosphere becomes noosphere. Noosphere is not fiction, it is not creating belief, and it is empiric generalization". These thoughts of his - namely that Man as a part of the biosphere using his intelligent activity can save and prevent the Earth of destruction and cataclysms, are adopted by Bulgarian scientists, too (Nikolov, 2013; Kostov, 2013).

The Noosphere Repairs the Consequences of the Technosphere and the Anthropocentris



Defending Vernadski" study the French scientist Teilhard de Chardin (1994) wrote in his book "Human Phenomenon" that "Man is not centre of the Universe, he is the thoughtful layer of the planet." These two humanistic scientists and their followers believed that „our counteraction to the regularities of the noosphere must not be expressed by despair but by reconsideration of ourselves" (Nikolov, 2013). All this obliges us to do research not only in the genesis of soils, but also in the noogenesis of Man and his role in conservation or destruction of soil resources. In the last decade soils have continuously and intensively been subjected to the impact of human activity. "Human activity changes the climate and nature, it converts soils, and for good or evil – it changes us." (Teoharov, 2011). Soil is the basic and major component of the Earth's ecosystem and the biosphere and as well as climate does, it changes very fast, but



not without Man" participation. The unreasonable and irresponsible statements and actions of some factors have recently attributed a political profile of the degraded and contaminated soils.

Planet Earth - call for reason, harmony and fertility.

Modern Man and the Consequences of the Technosphere and the Anthropocentris



International Soil Expedition



Food security problem - the main priority for the humanity

Modern Man builds up, contaminates and disturbs the integrity and basic functions of soil. However, it is a living system with a life-giving power – a unique natural resource, which creates and preserves material goods and spiritual values for the Man himself. Soil preserves the historical memory of civilizations. A proof of that is the archeological excavations in the country and the center of Sofia, where antique objects, Roman and Thracian gold treasures, etc., are found at depth of only 2-3 meters. The lack of knowledge of the functions and essence of soils removes Man not only from the habitat where soil is formed and lives on, but from Man's own habitat.

Soils are a part of the biosphere and Man should evaluate his actions towards them. We share the opinion that it is time for the noosphere to conquer the minds of modern societies and the conservative rationality to take control of the soil and human resources. The indulgent, non-scientific and liberal attitude to these resources is disastrous. The intensive development of agriculture and industry, which soils cannot bear any longer, will lead to an ecological catastrophe of the planet.

The nature of Man becomes a problem not only for soil and nature itself but also and for the man himself. Noosphere is a study, which may compensate for the consequences of human activity, the technosphere and the anthropocentris, if only the words of the first soil

scientists, said as early as 1909, are never forgotten: “Soil is that huge laboratory, where the preparation of the dead matter takes place, so that it can enter the blood circulation of life; soil is, so to speak, the living layer of the Earth’s globe. As a thin gentle diaper it covers the enormous body of the Earth and gradually spiritualizes this body”. Are these thoughts not the first signs for the appearance of the science of the noosphere in Bulgaria even before Vernadski himself created it? It is necessary for all Bulgarian scientists to continue the discussion with Academician Vernadski’s followers and to consider and take care of soil as if it were a little baby, covered in diaper and embraced by Mother Land.

The thoughtful layer of the Earth planet is summoned to protect and preserve the living layer of the globe.

References

- Antipov-Karataev, I.N., V. Galeva, I.P. Gerassimov, K. Enikov, E. Tanov, and I. Tyurin. 1960 (Eds.). The Soils in Bulgaria. Agricultural literature Publisher, Sofia, Bulgaria. (in Bulgarian)
- Aubert G. 1967. La classification des sols utilises en France. Paris.
- Aubert G. 1988. Referentiel pedologique Francais. INRA, 251 p.
- Boyadzhiev T. 1994. Soil Science, Agro-chemistry and Ecology, № 4, p.10-13, S. (in Bulgarian)
- Classification and Diagnostics of the Soils in the Soviet Union, 1977. M., Kolos, p. 220. (in Russian)
- Dushaufour, Ph. 1965. Precis de pedologie. Masson, Paris, 224 p.
- FAO. 1964. Preliminary definitions, legend and correlation table for the soil map of the world. (project). Rome, 16 p.
- FAO. 1998. World reference base for soil resources. Rome, 93 p.
- FAO. 2006. World reference base for soil resources. Rome, 91 p.
- Kovda V.A. 1955. An Attempt of Composing the World Soil Map, Scale: 1:500000. MSU, Moscow. (in Russian)
- Kovda V.A., E.V. Lobova. 1974. World Soil Map, Work of the International Congress of Soil Scientists, volume V, Moscow. (in Russian)
- Koinov, V. 1964. Classification and Systematics of Soils in Bulgaria, Soils in Southeast Bulgaria, S. BAS, p.231-245. (in Russian)
- Koinov, V., H. Trashliev, M. Yolevski, T. Andonov, N. Ninov, A. Hadzhiyanakiev, E. Angelov, T. Boyadzhiev, E. Fotakieva, S. Krastanov, and Y. Staykov. (1968). Soil map of Bulgaria at a scale of 1:400,000. GUGK, Sofia, Bulgaria. (in Bulgarian)
- Koinov, V. 1987. Soil Science, Agro-Chemistry and Plant Protection, № 5, p. 5-12, Sofia. (in Bulgarian)
- Kostov, R. 2013. Planetary Humanism of V.I.Vernadski and Pierre Teilhard de Chardin in the Idea of the Noosphere in : “Vernadski and the 21st Century, Geosphere, Noosphere, Symmetry”, Ivan Rilski Publ. House, S., p. 71-76. (in Bulgarian)
- Kubiena, W. 1950. Bestimmungsbuch und systematic der Boden Europas. Stuttgart, Enke, 441 p. (in Bulgarian)

- Nikolov, T. 2013. Status of the Planet in the Light of the Ideas of V.I. Vernadski of the Biosphere and Noosphere, ““Vernadski and the 21st Century, Geosphere, Noosphere, Symmetry”, Ivan Rilski Publ. House, S., p. 5-13. (in Bulgarian)
- World Soil Map. 1954. Scale 1:5000000. Publ. MSU, M.
- Pushkarov, N. 1913. Soil-Geological Description of the Sofia Field, Selected Works (1975). Publ. BAS, S., p. 23-87. (in Bulgarian)
- Pushkarov, N. 1920. Soil-Geological Sketch of the Pirdop Administrative District, Selected Works (1975), Publ. BAS, S., p. 23-87. (in Bulgarian)
- Pushkarov, N. 1931. Soil Map of Bulgaria, Scale 1:500000, S. (in Bulgarian)
- Stranski, I. 1946. Soil Science, Publ. University Printing House, S., p. 585. (in Bulgarian)
- Tanov, E. 1956. Medium-Scale Soil Map of PRB. Scale 1:200000, S. (in Bulgarian)
- Teoharov, M. 2004. Soil Science, Agro-chemistry and Ecology, № 4, p.3-13. (in Bulgarian)
- Teoharov, M. 2009. Technologies and Innovative Solutions for Agriculture, Ecology and Conservation of Soil Resources, AA- N. Pushkarov ISS, Publ. Ambrozia NTLtd, p.44. (in Bulgarian)
- Teoharov, M. 2010. National System of Services for Agriculture and Conservation of the Soil Resources, AA- N. Pushkarov ISS, Publ. Ambrozia NTLtd, p.20. (in Bulgarian)
- Teoharov, M. 2011. Words of the Patriarch of Bulgarian Soil Science, in “Soils and Land in Bulgaria – a National and Century-Old Treasure”, Publ. PSSE, S., p. 16-18. (in Bulgarian)
- USDA. 1990. Keys to Soil Taxonomy. 4-th edition, 422 p.
- Yolevski M., 1983, Short Diagnostics and Criteria of the Basic Taxonomic Subtypes of Soils in Bulgaria, Improved Taxonomic Scheme, Pushkarov ISSY, S., p. 44. (in Bulgarian)



Tropical soils: Importance, Research And Management

Ognyan Stoyanov Kostov

Nexus Technology Consultancy Sdn. Bhd., Kuala Lumpur, Malaysia.

Corresponding Author: Ognyan Kostov, e-mail: ognyan.kostov@gmail.com



Abstract

It has been reviewed papers and personal investigations about soil tropical soils fertility. It was pointed out the importance of tropical soils for quantity and quality of yields of many crops. It was discussed soil quality, soil degradation, integrated nutrient management, maximization of the use the use of organic materials, balanced use of inorganic fertilizers, minimizing losses of plant nutrients, methods for conservation cropping management of low productive soils, polices for soil and fertility management and composting waste to improve and maintained tropical soils fertility.

Key words: tropical soils, soil degradation, nutrient management, organic materials, composting, polices of soil fertility management.

Introduction

Soil supports the growth of plants which supply the world with food, biomass and renewable energy. It provides habitats for biodiversity, species and genes, and is a major source of raw materials. It also stores, filters, and transforms nutrients, substances and water, and it acts as a carbon sink in global climate regulation.

Soil fertility

Soil as one of the tree main components of the Atmosphere, water and air, play an important role for maintaining the life in the Earth. The short determination what is soil fertility is connected with its main ability to provide crops and microbes with essential nutrients. Additionally soil fertility give an effect on nutrient cycling, climatic change, carbon sequestration, soil erosion, soil organic matter, soil degradation, bioenergy carbon neutral (reduces emissions from fossil fuels (25%), carbon release of 5% thus supply photosynthesis of plants with CO₂ for their respiration, biochar sequestration carbon negative (reduces emissions from biomass), net carbon withdrawal from atmosphere (20%) and effect on tropical agroecosystem (www.organicagriculture.co; www.organicagriculture.co/soil-fertility-management.php; soil fertility, SSS-17)). “Soil quality” word was suggested in 1993 in a International Soil Science Conference (Budapest, Hungary) to replace word “soil fertility” Soil quality includes two more words such as: soil health and assessment of the farmers of soil productivity. But in the agricultural practice scientists and farmers still prefer to use “soil fertility”.

Results and Discussion

Factors influencing soil fertility are: 1. Infiltration of water; 2. Content of organic matter; 3. Soil structure; 4. Active soil life; 5. Exploitable depth; 6. Minerals; 7. Soil acidity (pH); 8. Sufficient drainage; 9. Release of nutrients; 10. Parent soil; 11. Ground water (Picture 1 and 2).

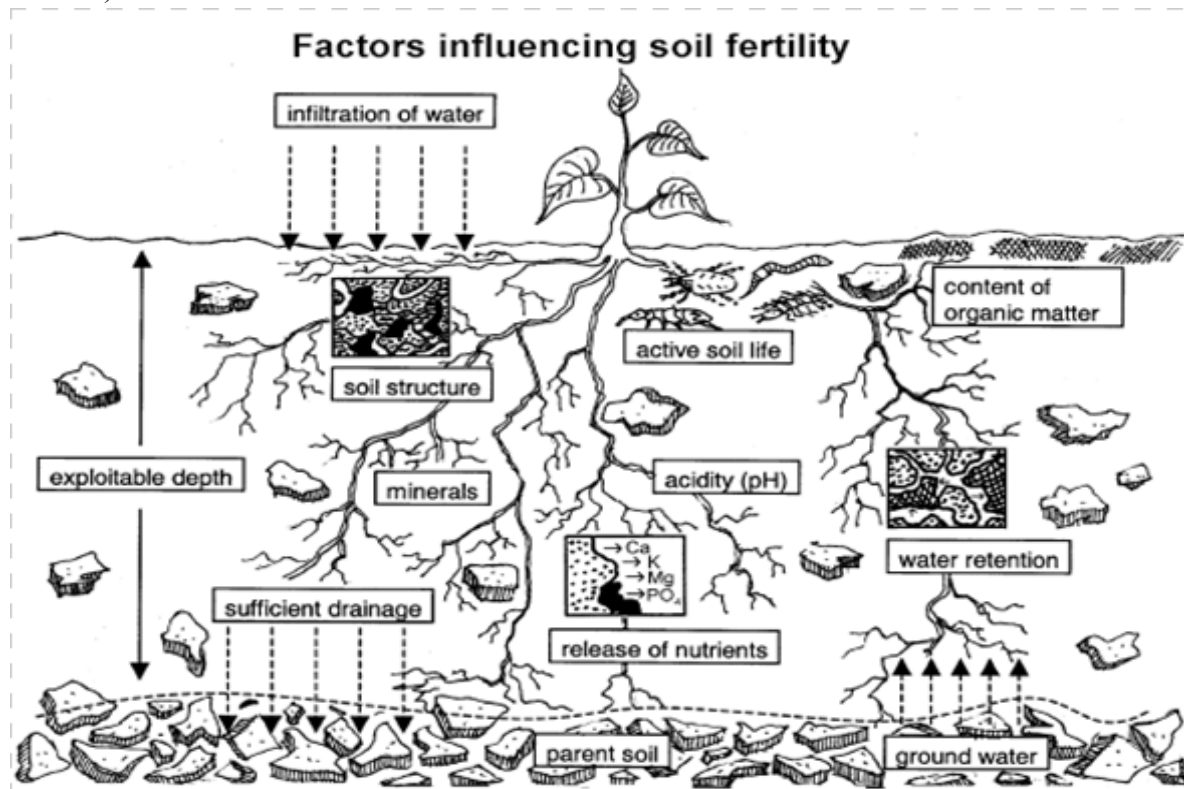


Figure 1. Factors affecting soil fertility (<http://agriinfo.in/default.aspx>)

Methods for soil fertility evaluation

Biological methods (<http://agriinfo.in/default.aspx?>):

1. Field trial; 2. Pot culture; 3. Seedling method; 4. *Aspergillus niger* method; 5. Toxicity test by carry out germination test; B. Use a visual symptoms of nutrient deficiency or toxicity test (growth of seeds and seedlings); C. Plant analyses methods: 1. Total elemental analyses; 2. Plant tissue tests; D. Soil analyses methods: pH, ammonium and nitrate nitrogen and their ratio, total number of microbial population of main physiological groups of microorganisms, number of sensitive microorganisms such as nitrifying bacteria, free living nitrogen fixing bacteria, symbiotic N_2 -fixers, spore forming bacteria and ratios between different groups of microorganisms



Figure 2. Soil with good fertility (<http://ourworld.unu.edu/en/recommended-reading-for-the-un-international-year-of-soils-2015>)

The most reliable tests for soil fertility are field tests (Booklet No. 353, SSS-17) but they are time consuming, laborious and expensive. Depending on the purpose they can be assessed: manures, composts, different fertilizers, water consumption and way of irrigation, breeding trials etc. Important steps to carry out such experiments are: site selection, layout, cultural operation, test phases, qualitative determination, quantitative determination, complex fertilizer trials, permanent manorial trials. Expected results can be plant growth, seed production, vegetative mass, swiftness of the fruits and their yield, appearance, how early yield will be available to the market, profitability etc.

Fewer indicators may be sufficient to assess soil quality

Although soil quality is best assessed using a wide range of indicators, a smaller set may be more practical and still provide the necessary information needed to choose between land management systems (Kostov and Lynch, 2002; Lima, A.C.R., Brussaard, L., Totola, M.R., et al., 2013). A soil quality index combines indicators into one value by prioritising (or weighting) them according to their importance in the context, for example, the type of crop or environmental factors will influence the weighting. Researchers studied: 1. Conventional tillage; 2. Pre germinated; 3. No tillage, the soil preparation done around two months before sowing. They did not found statistically significant differences between studied indexes. It appeared that more important for management practice have been soil texture suggesting that clay contain of 40-60% is more susceptible for influences from the chosen management system. Finally they accepted that smaller number of indicators can provide useful information for management decisions.

A new method for evaluating threats to soil biodiversity

Researchers concluded (Gardi et al. 2013, IYS, 2015) that there are not enough baseline information to assess effect to soil biodiversity from climatic changes, agriculture intensification or soil erosion. The authors used a mathematical model to quantify the relative severity of each threat based on experts' analysis. The top most severe threats emerged as intensive exploitation of land, decline of organic material found in soil, and habitat disruption. Further analyzing using mapping software demonstrated that soil biodiversity is under threat in 56% of EU territory. Of the area studied, 15% was classed as high, very high or extremely high threat. Authors pointed out that research and monitoring are urgently needed to protect soil biodiversity.

Increased concerns over fluvial carbon losses from deforested tropical peatlands. Over 20% more carbon could be being released by tropical peatlands than previously estimated, a new study suggests. The research highlights the large quantities of carbon lost to rivers from deforested and degraded peatlands in Indonesia, in addition to carbon released as CO₂ gas (Moore, S., Evans, C.D., Page, S.E. et al., 2013). The level of carbon in the water draining from the peat swamp forests was measured over a year at weekly intervals. The results indicated that the channels draining the degraded forest contained about 55% more organic carbon in the water than the channels draining the intact forest. The average loss from degraded peat swamp forests was calculated to be 97 grams of carbon per square metre of land per year (as opposed to 63 grams from the intact forest), and most of this was lost during the rainy season. The researchers estimated that the total amount of carbon being lost from the peatlands, including the water-borne carbon loss, is 22% higher than other estimates which only consider carbon lost as CO₂ gas. Based on these figures and data on different land uses across southeast Asia, they then calculated that there has been a 45% increase in organic carbon lost to rivers in Borneo, Sumatra and the Malaysian peninsula (from 4.7 to 6.8 million tonnes of carbon per year) since 1990, owing to the conversion of peat swamp forests into disturbed degraded peatland. For the whole of south-east Asia, peatland degradation was estimated to have produced a 32% increase in organic carbon lost to rivers. The study suggests that this may be an underestimate, because no data were available for the conversion of peatlands to industrial plantations, another important type of land use change.

Tropical Agriculture and the Environment

There are two theories in management of tropical agriculture and also to other world areas: 1. Relationship between population and soil productivity will go this way that soil soon will be degraded beyond recovery and population incomes will not be enough to survive. 2. Second theory is to keep soil productivity to a such level that permits you to recover soil fertility, maintain less erosion, use organic materials, apply biofertilizers, support biological nitrogen fixation and do not apply too high levels of mineral fertilizers thus big parts of them to be lost as N₂O. So systems as low impute fertilizers and partly organic are

the most suitable to maintain soil fertility and can make enough incomes to survive. (<http://athene.umb.no/emner/pub/eds215/lecturedevelopment.htm>; Kostov and Lynch, 2002)

Soil fertility management

1. Soil degradation and tropical agriculture. Soil is key factors affecting plant growth. The major functions of soils are to provide plants with nutrients, water and oxygen. Simply saying soil fertility is capacity of soil to support plants growth. Soil degradation are processes that negatively affect soil fertility. Soil properties affected by soil degradation are nutrient content, water holding capacity, topsoil depth, acidity, salinity, porosity, and soil biomass. The main processes causing soil degradation are: nutrient depletion, soil erosion, compaction, accumulation of harmful components (salinization and acidification); soil organic matter reduction. Soil degradation have serious economic consequences: lower return of investments in the agricultural sector, insufficient quantity and quality of the food, higher food prices, increased government expenditure on health, reduce government revenue due to less collected taxes on agricultural goods, flus to urban area, increased sedimentation of dams due to soil erosion. It is established that soil degradation have already significant impact on productivity of about 16% of the global agricultural land. Combining the new map of agricultural land with existing expert assessment of soil degradation suggest that 75% of crop land at Central America is seriously degraded, 20% in Africa (mostly pasture) and 11% in Asia. Soil degradation is the reason that many International Institutions emphasizing soil fertility management to enhance agricultural productivity.
2. Integrated nutrient management. Integrated nutrient management is a way to combat nutrient depletion. This is an approach to combine organic and mineral methods of soil fertilization with physical and biological measures for soil and water conservation. The main difference between natural and agricultural ecosystem is that in agricultural ecosystem the plant nutrients are constantly removed and exported. In soil fertility management the following principles are important: 1. Maximize use of organic material; 2. Balance use of inorganic fertilizers and 3. Minimize losses of plant nutrients. There is no written recommendation because of significant differences in alternative use of organic materials, access to market, price ratio of inputs and outputs, labor cost, farmers knowledge. Therefore local adaptation is always necessary. There are still discussion which approach farmers to follow: low input agriculture, high input agriculture, partly organic and full organic agriculture. Integrated nutrient management permit to take more flexible position because there are big differences in natural resources and socio-economic conditions. For example soil resources depend on the depth of soils. Deeper soil fix atmospheric C significantly in bigger amount.
3. Maximize the use of organic material. Agriculture in tropics highly depend on the release of plant nutrient from soil organic matter and from organic manure. Soil

organic matter play a critical role in maintaining soil fertility, water holding capacity, cation exchange capacity, acting as buffer against pH changes in soil, reducing surface crusting. However organic materials are not enough all over the world. Organic materials when are produced locally are more attractive because of lower price and lower transportation cost as compare to mineral fertilizers. However the following limitations to use organic fertilizers have to be mentioned: 1. Too low quantities are available to meet requirements of moderate yield; 2. Only a limited amount of phosphorous is supplied; 3. Application of manure is much more labor intensive, have low N content (1-2-3%) as compared to fertilizers which have 20-40% N; 4. Release of nutrients from organic sources is not well synchronized in time with plants demands for nutrients; 5. The quality of organic fertilizers differs greatly and their application should be different for different areas and crop systems. Generally low quality organic fertilizers/materials have to be used as surface mulch to protect soils from erosion and weed control but high quality organics fertilizers can be used as direct plant nutrient source. Combine application of advanced bio fertilizers, bio pesticide, organic farming methods will make soil fertility management sustainable in time.

There have been efforts to introduce so-called Low External Input Agriculture. It relies on cover crops, animal manure and improved fallows to maintained soil fertility (Kostov at all., 2002). There is a problem for cover crops to supply sufficiently phosphorous plants needs. Malaysian composts also do not have enough P to replace mineral fertilizer (Wan Rashida at all., 2004).

4. Balanced use of inorganic fertilizers. Fertilizers use varies greatly among continents. In 1994/5 fertilizers use per hectare averaged more than 216 kg in East Asia and 77 kg in South Asia. Compared to 10 kg in Sub-Africa and 65 kg in Latin America. Inorganic fertilizers have un immediate effect and very often well synchronized with plant growth. Recovery of N from leguminous plants incorporated into soil is 1-30%, while the recovery of fertilizer N is 20-50%. Fertilizers increase root and top biomass. Roots and crop residues left as mulch can contribute to improve soil organic matter balance (Kostov at all. 2002). Fertilizers use can also increase water use efficiency in crop production.

Inorganic fertilizers should be combine with organic material. In Malaysia well matured composts using sludge and POME during their production have good level of available N and K which can substitute inorganic fertilizers. Thus acidifying effect from fertilizers will be reduced and also improve soil physical characteristics. Using only inorganic fertilizer for soil fertility maintenance is not a suitable practice.

Nitrogen and phosphorous are elements which limits crop production in the tropics. Composts and organic fertilizers contain low level of P and for this reason application of inorganic P is very important in tropics. Rock phosphate is suitable P fertilizers but P is slow release also from this type of phosphorous. Single, double and triple superphosphate are more suitable because they release P faster and are water soluble.

So Rock Phosphate is more suitable for acids soils in Malaysia. Rock phosphate is competitive if supply at approximately 25% from the price of super phosphate. Nitrogen fixation also can be improved if P deficiency is removed. On soils without P deficiency can grow big variety of crops.

An indicator of rate of return is value cost ratio (VCR). This is the value of yield increased due to fertilizers application divided by the fertilizers cost. This value must be 2 or greater to cover yield risk. In wetland tropics application of inorganic fertilizers is very risky and one heavy raining can remove all applied fertilizers. This is the reason why in Sabah (Malaysia) during December and January farmers avoided to apply fertilizers. A combination of fertilizers use, soil conservation and water harvesting techniques can deduce the risk. Adjusting fertilizers application according to weather forecast is known as “responsive farming” and can increase profitability very high. Another technique is point application which reduce the price dramatically and increase fertilizers use efficiency.

5. Minimizing losses of plant nutrients. Losses from the agricultural system can be in the form of harvested product, soil erosion, gaseous losses and leaching. Soil erosion can be in two forms: water erosion and wind erosion. The removal of nutrients with the harvest product is not considered as lost but it is related with the desired profit. But from the point of view to maintain soil quality it have to be consider to prepare the next fertilizers application program to be balanced and especially to provide nutrients as organic materials (composts and manures). Soil erosion is very damageable factor. It removed not only nutrients but reduce topsoil depth, water holding capacity. Eroded material contain finer particles of the soil that are rich in nutrients. Soil erosion depend on such parameter as topsoil depth, rooting depth of plants, crops cultivation, distribution of soil nutrients in soil profile, water holding capacity of the different soil layers, and amount and intensity of rainfall. Bulgarian scientist Mianushev (2013) also reported strong reduction of soil erosion at application of inorganic and organic materials due to root and top mass increased. Application of manure is at about 25 t/ha every 3 years, green mass every 3 years, and usage of cover crops in rotation such as wheat, N₂ fixing grasses, barley etc. Losses from water erosion at the arable eroded land in Bulgaria are now 130,000 grain t/year. For the next 10 years it is expected losses to be 700,000 grain t/year only from water erosion. Economically effective fertilizers application of the main nutrients in tropical area are: N120,P120,K120/ha; for grasses the recommendation is: N100:P100:K100. The causes of soil degradation are both related to the natural resource base, farming practice and polices. It have to be realized that problems with soil erosion can not be solved by individual farmers. Now more attention is given not to the different structure of terraces but for crop cover or combination of both including tillage methods. For example zero tillage practice have been found the most effective.
6. What are recommendations of Natural Resources Conservation Service of USA. (www.nrcs.usda.gov). They recommend Conservation Cropping System Methodology. By introducing Conservation Cropping System management can

contribute: increase soil infiltration, to reduce the risk from droughts, floods, markets, maintain water quality, reduce $\text{NO}_3\text{-N}$ less in tile water, health soil and healthier profits, to avoid huge losses of non-renewable resources, not to change landscape, water quantity, less runoff, less flood damages, sediments and nutrient losses, improve air quality, save energy, healthy wildlife, Public cost savings, reduce inputs, filter sediments provides habitat, reduces pesticide application by half, reduce commercial fertilizer application, increase capture of the sun's energy by using winter cover crops to add an extra 4 to 5 money from photosynthesis, only one extra inch of water in August (saved through soil health practice) can mean an extra 20-40 bushels per acre in corn yield, reduce compaction and increase weed control. To make soil health priority through conservation cropping system you have to implement: a functioning no-till system, cover crops, nutrient management, pest management, crop rotation, buffers. Indiana's soil health strategy: 1. Established a state soil health specialist position; 2. Established area soil health team to identify local training and technical needs; prioritize contribution agreements, staffing decisions, developments of the tools, alternative work situations and mobile planning concepts; make soil health a priority in the Indiana communication plan, require NRCS Indiana employees meet skill level for soil health concept; support soil health as a training priority for all employees; ensure partners and leaders are aware of positive effect of conservation cropping system on soil health

7. Management of low productive soils There are low productive soils which need application of specialized technologies. *Heavy metal contaminated soils*: There are soils which after mining activity have not been used and their fertility have not been recovered. Usually these soils are acidic and contain more then one heavy metal over the standards. To neutralize further contamination to healthy soils must be take measures for re-cultivation. There are two approaches: a) USA approach is to cover the soil surface with CaCO_3 up to reach values of pH 7.3. But using this method plants, especially grasses, can not grow because at pH over 7 all trace elements are blocked and can not be taken by plants; b) second approach is to determine potential soil acidity (how much soil will be acidify during the coming times) and to apply CaO or CaCO_3 according to measured acidity. But in both case microbial diversity have to be recovered and these soil have to be treated with 20 cm compost layer (Kostov and van Cleemput, 2001). Then not sensitive grasses have to be used to cover the treated soils to avoid erosion processes. Salinized soils are managed by leaching and application of gypsum. Strongly eroded soils are planted with nitrogen fixing grasses and grass mixtures but before planting they are treated with big amount of compost or manure. Weathered soils which are typical for tropical conditions including Malaysia are treated with alkaline solution as bunch ash to neutralize exchangeable Al and then compost is applied to recover soil microbial diversity and structure of the soil. Application of humic and fulvic acids to these soils is very useful management practice. It was carried out a personal study in Belgium using: 4 Indonesian, 4 Malaysian and 4 Belgium soils with the same acidic pH of 4.5. Soils were also determine for availability of exchangeable (toxic) Al. It was found that Malaysian and

Indonesian soils showed exchangeable (toxic) Al but Belgium soils despite having the same acidity did have exchangeable Al due to its high organic matter content (2.8%). Acidified soils must not be treated with inorganic fertilizers and must be treated with CaO plus organic fertilizers such as composts to recover their structure and removed toxic (available) forms of heavy metals. Soils with low fertility will result in deforestation, desertification, loss of biodiversity and influenced climatic change.

8. Polices for soil fertility management. The process of creating a more sustainable and productive agriculture requires public action along many paths. Political/economic factors are of vital importance for soil fertility management such as prices of input and output, access to credit and related interest rates, infrastructure and markets. Policies which affect these factors are fiscal and monetary policies, credit policies, and investment in infrastructure. For example exchange rate will affect the price of fertilizers. Investment in soil fertility management will be warranted when there is balance between private and social cost. For example an investment may give too little return in order to be an interesting option for the farmer, may be beneficial from a public point of view. The private farmers are more focused on short term benefits than society. The benefits of the society of erosion control programs can be related to reduction of poverty, to avoid siltation of dams, and destruction of roads. Private farmers have also to be interested to substitute bigger parts from inorganic fertilizers by making their own composts/manures using plant residues and other organic materials. So farmers have to be interested more in new technologies which can strengthen the integration between crops and livestock production, enhance recycling of organic materials, developing low cost and efficient methods for fertilizers application and moisture conservation. Fertilizers used always have to be accompanied by recycling of organic materials to ensure soil microbial diversity (Gardi et al., 2013), to avoid pollutions of ground waters and rivers, waterlogging and salinization of irrigated land, human health problems related to pesticide use, to reduce CO₂ and N₂O emissions to reduce global warming effect, to uptake CO₂ from air (more fertility and deeper soils fix more atmospheric CO₂) and to keep soil quality for future generations. Soil fertility management have fundamental importance for the development and sustainability of tropical agriculture production.
9. Composting wastes to improve and maintain soil fertility. Special attention have to be given to tropical composting of wastes. (Kostov and van Cleemput, 2001; Kostov and Ngan, 2002; Vladeva and Kostov, 2002; Kostov et al., 2004; Wan Rashida et al., 2004; Kostov et al., 2005; Kostov 2008;). Application of all kinds matured composts to tropical soils will increase soil organic matter, will protect soils from soil erosion, will improve physical properties of soils, will increase water holding capacity of soils, will supply with nutrients plants in accordance with their needs, reduce acidifying activity of mineral fertilizers (EFB compost have pH =8.5-9) , will have very strong bioremediation effect on available (toxic) heavy metals, aluminum and arsenic and increase the quantity and quality of the yield and finally will increase profitability of palm oil plantations, palm oil mills and all types of agricultural practices occupied

with tropical plants. Using zero waste discharged composting technology we can contribute to increase humus content of tropical soils by 1.4 kg humic acid, 7.2 kg organic C, 1 kg K_2O , 0.4 kg P_2O_5 , 0.2 kg MgO , 0.1 kg CaO , 0.4 g B at application rate 20 kg compost/palm oil tree/year. Also compost contain trace elements. It was established by huge area experiment (in ha Palm Oil Plantation in Sabah, Lahad Datu) that additional to mineral fertilization, the application of humic acid (imported from USA) to palm oil plantations at rate of 300 g/tree/year can increase the yield at Sabah area (Malaysia) up to 37t FFB (Fresh Fruit Bunches)/ha/1-3 years. Also it have to be taken into account that optical properties of compost humic acids which are not the same as compare to very old soil humic acids. Amount of fulvic acid in composts is also very important to soil fertility because they balanced photosynthesis processes in plants and regulate release of carbon by root system to soils and soil microorganisms. Compost have also strong bioremediation effect on heavy metals and As because it pH is near to 9 and it can increase soil pH in active zone of young roots.



Picture 3. Turning windrows to optimize microstructure, O_2 and moisture content



Picture 4. Biocontrol properties of compost on banana diseases



Picture 5. *Biocontrol properties of zero waste discharged compost*

Conclusion

The 68th UN General Assembly declared 2015 the International Year of Soils (IYS) (A/RES/68/232). (<http://www.fao.org/soils-2015/about/en/>)

The Food and Agriculture Organization of the United Nations has been nominated to implement the IYS 2015, within the framework of the Global Soil Partnership and in collaboration with Governments and the secretariat of the United Nations Convention to Combat Desertification.

The IYS 2015 aims to increase awareness and understanding of the importance of soil for food security and essential ecosystem functions.

The specific objectives of the International Year of Soils 2015 (IYS) 2015 were to:

- Raise full awareness among civil society and decision makers about the profound importance of soil for human life;
- Educate the public about the crucial role soil plays in food security, climate change adaptation and mitigation, essential ecosystem services, poverty alleviation and sustainable development;
- Support effective policies and actions for the sustainable management and protection of soil resources;
- Promote investment in sustainable soil management activities to develop and maintain healthy soils for different land users and population groups;
- Strengthen initiatives in connection with the SDG process (Sustainable Development Goals) and Post-2015 agenda;
- Advocate for rapid capacity enhancement for soil information collection and monitoring at all levels (global, regional and national).

Soils are a finite natural resource and are nonrenewable on a human time scale. Soils are the foundation for food, animal feed, fuel and natural fiber production, the supply of clean water, nutrient cycling, buffers for floodings and droughts and range of ecosystem functions. About 80% of soils are not irrigated but they produce 60% from the global agriculture production. The area of fertile soils covering the world's surface is limited and increasingly subject to degradation, poor management and loss to urbanization. Increased awareness of the life-supporting functions of soil is called for if this trend is to be reversed and so enable the levels of food production (world food production have to be increased by 60% but for developing countries by 100%) necessary to meet the demands of population levels predicted for 2050. Soils play key role for carbon cycle and can fix CO₂ thus reducing negative effect of climate changes. Soils maintain also biodiversity, support growth of the plants and produce foods, fuels, medicine products and drinking water. Also 33% from soils are moderate to strongly degraded due to consumption of nutrients, acidification, salinization etc. New agricultural practices have to be applied such as agroecology methods, biological agriculture, zero tillage suitable crop rotation, low impute agriculture, and forest agriculture. (<http://www.fao.org/soils-2015/about/en/> ; <http://ourworld.unu.edu/en/recommended-reading-for-the-un-international-year-of-soils-2015>; www.bsss.bg)

References

- Gardi, C., S. Jeffery, A. Saltelli. 2013. An estimate of potential threats to soil biodiversity in the EU. *Global Change Biology*. 19(5): 1538-1548. DOI: 0.1111/gcb.12159
- Kostov, O., and O. Van Cleemput (2001). Microbial activity of Cu contaminated soils, and effect of lime and compost on soil resiliency. *Compost Science and Utilization*, 9 (4): 336-351.
- Kostov, O., T. Y. Ngan, H. H Ngan. 2005. Method of making compost from oil palm harvest refuse material. Malaysian Patent Application No. PI 2004862, Full Grant No. MY-145029-A.
- Kostov, O. & T. Y. Ngan. 2002. Effect of lime and composts on bioremediation of copper and yield of lucerne (*Medicago sativa*) in Cu contaminated vineyard soil. In: *Proceedings of International Symposium on Composting and Compost Utilization*. May, Columbus, Ohio, USA, pp. 1061-1072.
- Kostov, O. 2008 Composts: production, quality and application. *Agroworld*, March 2008.201, pp .60-63
- Kostov, O., E. Filcheva, T. Y. Ngan. 2004. Effect of inoculated wheat straw on humification processes of eroded soil In: (Ladislau Martin-Neto, Debora Marcondes Bastos Pereira Milori, Wilson Tadeu Lopes da Silva, eds) "Humic substances and soil and water environment" Embrapa, July 25-30, Sao Pedro, Brazil, pp. 40-41.
- Kostov, O., J. Lynch & L. Elliott. 2002. Effect of inoculated wheat straw on the resiliency of eroded soil. *Ecology and Future*, 1: 24-31.
- Myanushev E. 2013. Effectiveness of fertilization at strongly eroded arable lands. *Crops Science*, August, 3: 22-23
- Lima, A.C.R., L. Brussaard, M.R. Totola. 2013. A functional evaluation of three indicator sets for assessing soil quality. *Applied Soil Ecology*. 64:194-200. DOI: 10.1016/j.apsoil.2012.12.009
- Moore, S., C.D. Evans, S.E. Page. 2013. Deep instability of deforested tropical peatlands revealed by fluvial organic carbon fluxes. *Nature*, 493:660-664. Doi: 10.1038/nature11818

Soil fertility: Method for evaluation. Booklet No. 353; Soil Science: SSS-17

Vladeva, D. & O. Kostov, 2002. Effect of added to soil organic materials and compensated dose of fertilizer nitrogen on the yield of maize and winter wheat. In: *Proceedings "Ecology and health"* Agrarian University, Plovdiv, Bulgaria, pp. 45-50.

Wam Rashida Kadir, Rozita, A., Hoi, K. and O. Kostov. 2004. Amelioration of composting process by fertilizers. *Compost Science and Utilization*, 12 (1); 80-85

<http://agriinfo.in/default.aspx>

<http://athene.umb.no/emner/pub/eds215/lecturedevelopment.htm>

www.nrcs.usda.gov

<http://www.fao.org/soils-2015/about/en/>

<http://ourworld.unu.edu/en/recommended-reading-for-the-un-international-year-of-soils-2015>

www.bsbs.bg (Bulgarian Soil Science Society)

www.organicagriculture.co

www.organicagriculture.co/soil-fertility-management.php)



Characteristics of Rendzinas in the Ludogorie Region

Vladimir Ilinkin*, Simeon Bogdanov**, Antonia Goleva**

*Institute of Biodiversity and Ecosystem Research at the Bulgarian Academy of Sciences, Sofia, Bulgaria

**University of Forestry – Sofia, Bulgaria

Corresponding Author: Vladimir Ilinkin, e-mail: ilinkin@mail.bg



Abstract

The paper presents results from an investigation on soils located in the Ludogorie region. Rendzinas (Rendzic Leptosols, FAO, 2006) have been studied. They are situated in the Lower forest vegetation zone (0–600 m a.s.l.) of the Moesian forest vegetation area. Soil samples have been taken from seven soil profiles. The study covers an area of 3000 m². The factors of soil formation have been characterized. Soil physical and chemical properties have been investigated. The results have been processed by a statistical programme. The arithmetic means (M) and standard deviations ($\pm$ SD) have been calculated.

The studied soils are characterized by favourable physical properties, e.g. water-resistant crumb and granular structure, porosity and bulk density. Their low supply of plant available water is due to the high permeability of the parent material.

The tendency of calcium to form complex insoluble compounds with humic substances (Knežević & Košanin, 2010) is a prerequisite for reduced accessibility of N and humus, although are not in low contents.

The calcium content is naturally higher given the specific features of the parent material. Antagonism between the ions of Ca and K, Ca and Mg (Jorova, 1995) is a prerequisite for reduced accessibility of K and Mg, although, soil texture with a predominant presence of silt and clay, allows for higher nutrient content than that of other primitive soils.

Key words: Rendzic Leptosols, factors of soil formation, physical properties, chemical properties.

Introduction

The sustainable development and productivity of forest plantations depend to a great extent on the silvicultural properties of the soil. Soil characteristics determine the existence and normal functioning of ecosystems. Based on studies on soil composition and properties forestry activities can be planned properly in such a way, as to ensure the effective and environmentally friendly use of forest resources.

Rendzinas were described for the first time in Bulgaria by N. Pushkarov as “Humus-Calcareous soils” (Pushkarov, 1938). Later Koynov (1968) coined the term “Humus-Calcareous soils” (Koynov, 1968), which is still used today as a synonym of Rendzinas. They

are defined as soils formed on carbonate-rich rocks under different climatic conditions (Duchaufour, 1965). Rendzinas are mostly loose soils with good permeability, regarding their shallow profile with lower water capacity they have usually less water supply (Paganová, 2007).

According to the basic classification of soils in Bulgaria (Penkov et al., 1992), Rendzinas soils belong to the Leptosol soil group. The soils belonging to this soil group are intrazonal and occur mainly in mountainous, semi-mountainous and hilly sloping terrains, where environmental conditions favour physical weathering and intense erosion, as well as specific soil-forming rocks. The soils are characterized by a thin, dark or light humus horizon located on a solid rock or on loose weathering materials (Donov, 1993; FitzPatrick, 1986; Frisby, 1961). Rendzinas occupy about 2.7% of the country's territory (Gyurov & Artinova, 2001), and their distribution is related to the presence of limestone. In Northern Bulgaria Rendzinas are found among Chernozems (occupying 21% of the country's territory (Teoharov et al., 2015; Hristov, 2009) and Gray forest soils (occupying 16% of the country's territory (Donov, 1993), around Varna, Shumen, Pleven, Montana, Lovech, etc., and in Southern Bulgaria among Vertisols and Cinnamonic Forest soils, around Burgas, Aytos, Chirpan, etc. In the mountains they occur among Brown forest soils (Fig. 1). The main soil-forming processes that have resulted in the formation of Rendzinas are the formation and accumulation of humus in a Chernozem type of soil formation (Donov, 1993; Malinova, 2010). Humus-accumulating layer is formed out not only by means of herbaceous vegetation, but also exists in forests with no sod (Kyrylchuk, 2017; Kutrovskiy & Val'Kov, 2006). Thus it should be assumed that humus-accumulating layer of Rendzinas is formed out: a) in herbaceous cenoses, b) in forest cenoses with herbaceous cover, c) in forest cenoses with no sod (although participation of sod in the initial humus formation is impossible to deny). The biogeocenotic diversity of vegetation in different bioclimatic zones varies from boreal to tropical with various humidity conditions (Kutrovskiy & Val'Kov, 2006).

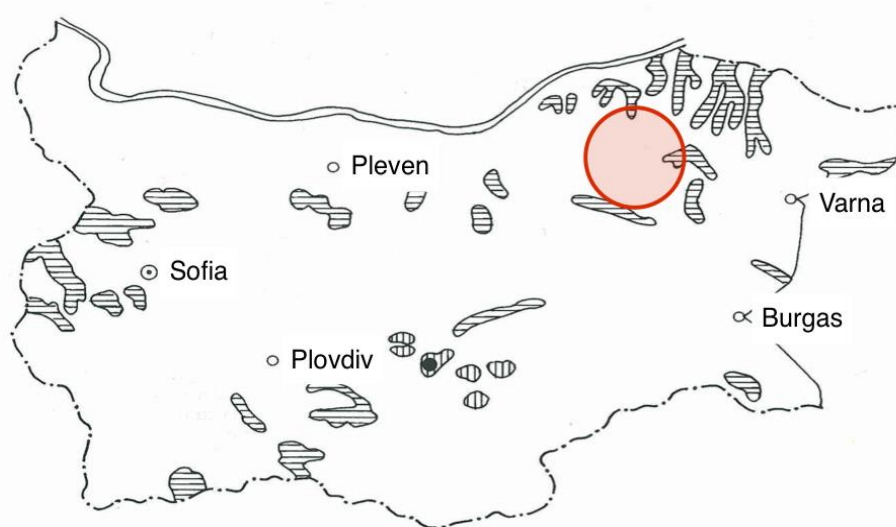


Fig. 1. Distribution of Rendzinas in Bulgaria and subject of the study (Koynov et al., 1998)

The purpose of this study is to analyse key properties of Rendzinas, as well as the factors of soils formation in the Ludogorie region, in order to facilitate the planning and implementation of activities related to the restoration and increase of productivity of forest ecosystems in the region.

Material and Methods

The subject of our study are Humus-Carbonate soils (Rendzic Leptosols, FAO, 2006) occurring in Ludogorie region. They are found in the Lower forest vegetation zone (0 - 600 m above sea level) of the Moesian forest vegetation area (Zahariev, 1979), Ludogorie subregion (Fig. 1). The studied area covers 3000 m² (Fig.1). The seven soil pits were made at representative plots whose slope did not exceed 10%. The samples were taken at a depth of ~ 0 - 25 cm and 25 - 40 cm

The following methods were used to analyze the soil samples:

- bulk density (Q), according to the Kachinsky method (Donov et al., 1974);
- relative density (D) by the pycnometer method (Donov et al., 1974);
- total porosity (P) through calculation from bulk density and relative density (Donov et al., 1974);
- water resistance (percentage of water resistant aggregates), by Adrianov's method (Donov et al., 1974);
- plant available water capacity (PAWC), by a laboratory method, through calculation from field capacity and permanent wilting point (Donov et al., 1974);
- soil texture, using the sedimentation method (ISO 11277);
- humus content by the Turin method (Donov et al., 1974);
- Total N content, by a modified version of the classic Kjeldahl method;
- C/N ratio – calculation method;
- content of mobile forms of Mg, Ca, Na and K, by using atomic absorption spectroscopy (extraction of 0.1 mol/l solution of BaCl₂);
- soil acidity (pH in water extraction and CaCl₂ extraction) – measured potentiometrical;
- CaCO₃ by Shaibler's method (NEN-ISO 10693).
- The results have been statistically processed using the STATISTICA 6 software. The arithmetic means (M) and standard deviations ($\pm$ SD) have been calculated.

Results and Discussion

The soil forming factors are important conditions that influence the nature, direction and speed of soil forming processes (Donov, 1993). The key factors are climate, biota, topography, and parent material.

The climate has a direct influence on the temperature and moisture of the soil, and an indirect one on the biota. In terms of climate, the subject of study falls within the European continental climate zone, the temperate continental climate subzone, middle climatic region of the Danubian hilly plain (Forest management plan, 2013). The average annual temperature of the studied area varies between 10.6 and 11.7°C, the average annual rainfall from 493 - 616 mm, with a peak rainfall in June and a minimum in February or March. The vegetation

period lasts approximately 6 ½ months. The winter is cold and relatively dry with an average temperature in January of -2.1°C. There is small amount of rain in the range of 85 - 120 mm, and the number of days with solid snow cover average 41-63. The summer is relatively warm with an average temperature in July ~ 20.2°C. There is significantly more rainfall in the summer than in the winter, and the amount of rain ranges between 160 - 230 mm. This is due to the hilly *terrain* typical of this region and is favourable for the formation and development of internal mass convective clouds and the frequent occurrence of showers (Forest management plan, 2013).

When the amount of rainfall increases and the vegetation cover decreases, the leaching process, which involves the release of base cations, including carbonates, intensifies. This may gradually convert Rendzinas into the respective zonal soil type. Higher plants are the most significant *biotic* factors that shape the formation of soils, the microclimate, supply the soil with organic matter and influence its composition and properties (Donov, 1979).

The plants involved in the process that formed the studied soils are mainly species that grow in alkaline soils. Leter Cupać et al. (2007) in the forest sites, predominating were deciduous species, mostly oak (*Quercus cerris* L. and *Quercus pubescens* Willd.) with occasional hawthorn (*Crataegus* spp.), hornbeam (*Carpinus* spp.) and ash (*Fraxinus* spp.) trees.

The zonal oak forests are dominated or co-dominated by Turkey oak (*Quercus cerris* L.), Hungarian oak (*Quercus frainetto* Ten.), field maple (*Acer campestre* L.), flowering ash (*Fraxinus ornus* L.), field elm (*Ulmus minor* Mill.), silver linden (*Tilia tomentosa* Moench), spindle tree (*Euonymus verrucosus* Scop.), etc. The shrub communities consist of common hawthorn (*Crataegus monogyna* Jacq), blackthorn (*Prunus spinosa* L.), smoke tree (*Cotinus coggygria* Scop), common lilac (*Syringa vulgaris* L.), etc. The grass vegetation also consists mainly of calciphilous species such as zigzag clover (*Trifolium medium* L.), wood false brome (*Brachypodium sylvaticum* (Huds.) Beauv), pheasant's eye (*Adonis vernalis* L.), bloody geranium (*Geranium sanguineum* L.), purple gromwell (*Lithospermum purpureocaeruleum* L.), bellflower (*Campanula bononiensis* L.), etc.

The *parent material* is the main soil-forming factor in the formation of Rendzinas. their formation and distribution are mainly related to the chemical and mineral composition of the carbonate parent rock (Donov, 1993), as well as to its physical, chemical and mineral properties. The soil texture, structure and soil reaction depend largely on the parent material (Donov, 1993; Malinova, 2010). The main parent materials of the studied soils are limestone, as well as marlstone. Limestone is made mainly of calcite (CaCO₃), which is either in a finely crystalline state or a solid mass. Marlstone is made of different proportions of clay and calcareous materials, and hence has properties inherent to clay and limestone, i.e. it becomes pliable when wet and effervescent when treated with hydrochloric acid (Petrova & Bogdanov, 2012). The soils profiles of the studied Rendzinas is characterized by a total thickness of ~ 40 cm. The morphological structure can be expressed by the designation Ak – Dk or Ak - Ck. The humus-accumulative A-horizon containing a carbonate skeleton (expressed by means of the suffix *k*) is dark to black and is enclosed by a hard carbonate rock (Dk) or weathered materials (Ck). The thickness of this horizon is relatively big, and equals the total thickness of the soil. Limestone and marlstone rocks hearly take up the entire profile. The structure is “crumb” and “granular”. Based on their rocks (hard and soft), at sub-type

level the studied soils fall between the common Rendzinas (Haplic) and Pararendzinas (Hypercalcic).

The data of the physical parameters change slightly with the soil profile depth (Table 1). This coincides with the lack of texture differentiation typical of Rendzinas (Patterson, 1982.). The bulk density (Q) is 1.16 g/cm³ at 0-25 cm depth and 1.33 g/cm³ at 25-40 cm depth. The relative density (D) is 2.57 and 2.61 respectively. The total porosity (P) is relatively high, 54% in the upper (0-25 cm) and 49% in the lower (25-40 cm) layer. These results indicate favourable physical and mechanical properties which result in lack of stickiness and crust formation and low resistance to cultivation. The aggregate composition of the studied soils is characterized by high water resistance, and their percentage is close to the maximum 99.5% at 0-25 cm depth and 99.0% at 25-40 cm depth (Table 1). This is consistent with the high content of humus and calcium, which play a major role in the formation of a water resistant structure.

Table 1. Physical properties of the soils

Depth, cm	n	Q g/cm ³		D		P %		Water resistant aggregates %		PAWC mm	
		M	±SD	M	±SD	M	±SD	M	±SD	M	±SD
0-25	7	1.16	±0.01	2.57	±0.01	54	±1	99.5	±0.5	49	±4
25-40	7	1.33	±0.02	2.61	±0.01	49	±1	99.0	±0.5		

The plant available water capacity (PAWC), which represents the amount of soil moisture absorbed by plants, is relatively low, 49 mm (Table 1). This can be explained by the relatively small total thickness of the soil, and mainly by the specific features of the parent material. The high permeability of limestone ensures rapid water drainage.

Geological parent material was found to have a predominant influence on the texture of Rendzinas soils (Cupać et al., 2006b). Rendzinas are soils in which the texture varies from loamy to clay-loamy (Venturella, 2004) and clay textured (Tümsavaş & Aksoy, 2008). The soil texture data are presented in Table 2. The fractions of sand (63 µm – 2 mm), silt (2 µm – 63 µm) and clay (< 2 µm) were determined. According to the texture, the soil falls into the "Silty clay loam" category at 0-25 cm depth and into the "Silt loam" category at 25-40 cm depth (FitzPatrick, 1986). In both layers the silt fraction has the highest percentage, 52.14% and 62.46%, respectively. In the upper (0-25 cm) layer the sand fraction is 11.29%, and the clay, 36.61%. In the lower (25-40 cm) layer the percentage of the sand fraction almost doubles, 18.61%. This increase is mainly at the expense of clay. Its percentage decreases almost two-fold – 18.93%. The sand fraction is assumed to be completely chemically inactive, as it is composed mainly of primary materials, particularly quartz (Petrova & Bogdanov, 2012). The chemical activity of the soil is determined by the silt fraction, if it prevails, and mostly by the relative share of the clay fraction. The results from the study on the chemical composition of the soils, presented in Tables 3 and 4, confirm this statement. The significant silt and clay contents also suggest that there is comparatively better

availability of nutrients than in other Primitive soils in the Leptosols group, to which the studied Rendzinas also belong.

Table 2. Soil texture

Depth, cm	n	Sand %		Silt %		Clay %		Texture class
		M	±SD	M	±SD	M	±SD	
0-25	7	11.29	±0.42	52.14	±0.71	36.61	±0.53	silty clay loam
25-40	7	18.61	±5.28	62.46	±5.60	18.93	±0.35	silt loam

Humus content is mostly high (Harbar & Poznyak, 2016), and rarely medium, in the A horizon (Cupać, 2006a). Rendzinas are predominantly rich and very rich in total nitrogen in the uppermost layer of horizon A, and medium or well supplied in the layer below it. Enrichment of humus in nitrogen, shown as the C:N ratio, is mostly medium, and rarely low (Cupać, 2006a).

The black colour in the humus-accumulative horizon is due to the significant humus content. The mineralization of organic matter is hindered by the large amounts of CaCO_3 and low moisture, which are due to the characteristics of the parent rock. Hence, humic substances accumulate and the humus-accumulative horizon thus formed is relatively thick for primitive soils (Bogdanov et al., 2015).

Table 3 presents the results from the study on some chemical characteristics of the soil. The humus content is relatively high, 6.75% in the upper (0-25 cm) layer and 2.88% in the lower (25-40 cm) layer, which is typical of the common Rendzinas. The amount of total nitrogen in both layers isn't high, i.e. 0.163% and 0.057%, respectively.

The ratio of the amount of total carbon to the amount of total nitrogen (C/N) in the soil indicates the degree of decomposition of organic matter. The values of this indicator are higher in the upper (22.54) layer than the lower layer and (25.67). In our study C/N ratio is higher than the C/N ratio in other study of Rendzinas (Radmanović et al., 2015b). This is indicative of the rate of mineralization of organic matter, which largely depends on the microbiological activity of the studied soils under the complex influence of the soil-forming factors. The parent rock plays a major role as its specific features determine the prevalence of humus forming processes and humus accumulation over the mineralization processes in the soil formation of chernozems.

Later Radmanović et al. (2015a) Rendzinas indicate the dominant influence of soil chemical characteristics (carbonate content and pH value). The soil reaction is consistent with the characteristics of the parent materials and is neutral to slightly alkaline (Table 3). The higher pH in the lower (25-40 cm) layer may be explained by the proximity to the parent material and the increased presence of carbonates in the parent rock.

Table 3. Chemical composition and soil properties

Depth, cm	n	Humus %		Total N %		C/N		pH /H ₂ O/		pH /CaCl ₂ /		CaCO ₃ %	
		M	±SD	M	±SD	M	±SD	M	±SD	M	±SD	M	±SD
0-25	7	6.75	±0.41	0.163	±0.001	22.54	±0.72	6.63	±0.37	6.21	±0.54	8.65	0.06
25-40	7	2.88	±0.08	0.057	±0.016	25.67	±2.08	7.66	±0.05	7.17	±0.05	23.18	0.09

The pH values in the CaCl₂ extract are 6.21 in the upper (0-25 cm) layer and 7.17 in the lower (25-40 cm) layer (Table 3). This indicates that the exchangeable acidity, which is an indicator for degradation processes, is small (Ignatova & Damyanova, 2010).

In general, the studied soils are poor in mobile nutrients such as K (a crucial element of plant nutrition and is the second largest nutrient assimilated by plants after nitrogen (Marschner, 2012)), Na and Mg (excluding Ca) (Table 4). These elements have important implications both for the soil properties and for plant development, and their content in the different soil layers depend on the combination and influence of the soil-forming factors.

Table 4. Content of some of the major mobile nutrients in the soil

Depth, cm	n	Mg mg/100g		Ca mg/100g		Na mg/100g		K mg/100g	
		M	±SD	M	±SD	M	±SD	M	±SD
0-25	7	13.1	±2.1	280.1	±13.9	3.1	±0.5	5.7	±1.9
25-40	7	7.2	±0.5	297.2	±22.3	2.1	±0.6	2.7	±0.2

The results obtained show a higher content of Ca, which is related to its presence in the parent material. The tendency of calcium to form complex insoluble compounds with humic substances and water-resistant aggregates of crumb and granular structure (Knežević & Košanin, 2010). On the other hand, the presence of calcium carbonate reduces solubility and the availability of nutrients.

Conclusions

The complex influence of soil formation factors determines a chernozem type of soil formation with a higher intensity of humus formation and humus accumulation processes. This is a result of the dominant role of the parent material and its properties as a soil-forming factor.

The studied Rendzinas soils are suitable for wide variety of crops (FitzPatrick, 1986). They provide favourable conditions for the development of forest tree species such as Turkey oak (*Quercus cerris* L.), Hungarian oak (*Quercus frainetto* Ten.), field maple (*Acer campestre* L.), flowering ash (*Fraxinus ornus* L.), field elm (*Ulmus minor* Mill.), silver linden (*Tilia tomentosa* Moench), black pine (*Pinus nigra* Arn.), etc.

The studied soils are characterized by favourable physical properties, e.g. water-resistant crumb and granular structure, porosity and bulk density. Their low supply of plant available water is due to the high permeability of the parent material.

The humus and total nitrogen are not in low contents, but the tendency of calcium to form complex insoluble compounds with humic substances (Knežević & Košanin, 2010) is a prerequisite for reduced accessibility of N and humus.

The calcium content is naturally higher given the specific features of the parent material. Antagonism between the ions of Ca and K, Ca and Mg (Jorova, 1995) is a prerequisite for reduced accessibility of K and Mg, although, soil texture, with a predominant presence of silt and clay, allows for higher nutrient content than that of other primitive soils.

Activities for the restoration and productivity increase of the ecosystems in the region should be planned in accordance with soil characteristics and particularly with its specific chemical composition. The high Ca content limits nutrient assimilation. This requires that action be taken to improve the nutrient availability in these soils to meet the requirements of plant species.

References

- Bogdanov, S., Sl. Savev, Evg. Tsavkov. 2015. Investigation on humus-carbonate soils in the Western Balkan mountains foothill. Environmental engineering and environmental protection. Issue 3/2015, pp. 29-35. (in Bulgarian)
- Cupać, S., Đorđević, A., L. & L. Jovanović. 2006a. Effect of decarbonation and land use on humus content and its nitrogen enrichment in rendzina soils. Soil and Plant.
- Cupać, S., Đorđević, A., L. & L. Jovanović. 2006b. Soil texture of calcaric and non-calcaric rendzina soils in Serbia. Soil and Plant.
- Cupać, S., Đorđević, A., L. & L. Jovanović. 2007. Effect of land use on group and fractional composition of humus in rendzina soils in Serbia. Journal of Agricultural Sciences, 52(2). pp. 145-153.
- Donov, V. 1979. Forest soil science. Zemizdat. p. 411. (in Bulgarian)
- Donov, V. 1993. Forest soil science. Martilen Publishing House. p. 430. (in Bulgarian)
- Donov, V., Sv. Gencheva, K. Yorova. 1974. A manual for practical seminars in Forest soil science. Zemizdat. pp. 93-174. (in Bulgarian)
- Duchaufour, P. 1965. *Precis de Pedologie*. Soil Science. p. 587.
- FitzPatrick, E. A. 1986. *An introduction to soil science* (No. Second Edition). Longman Scientific & Technical Group UK. p. 256.
- Forest management plan. 2013. SFE Seslav. Nishava K&T OOD. (in Bulgarian)
- Frisby, M. E. 1961. The Rendzina soils of the Magnesian series in Durham (Doctoral dissertation, Durham University). p. 130.
- Gyurov, G., N. Artinova. 2001. Soil Science. Macros Publishing House. Plovdiv. ISBN 954-702-064-1. p. 474. (in Bulgarian)
- Harbar, V., S. S. Poznyak. 2016. Genesis and Properties of Rendzinas in the Podilski Tovtry. Polish Journal of Soil Science, 48(2), 229.

- Hristov, B. 2009. Pedometric and taxonomic characteristics of primitive soils formed on the soft rocks in the Chernozem area in Northern Bulgaria. Dissertation. Archive of Soil Science Institute "N. Pushkarov", Sofia, p. 147. (in Bulgarian)
- Ignatova, N., S. Damyanova. 2010. Critical loads of pollutants – one of the tools for the management of the sustainable development of beech forests. Management and sustainable development, 1/2010 (25), pp. 290-297. (in Bulgarian)
- Jorova, K. 1995. Investigation of soil-tree plants in fertilization and contamination. Habilitation study. p. 305. (in Bulgarian)
- Knežević, M., O. Košanin. 2010. Rendzinas in the community of beech, fir and spruce with Scots pine in NP'Tara'. Glasnik Šumarskog fakulteta, (101), 101-111.
- Koynov, V. 1968. Soil map of Bulgaria. Scale 1: 400,000. S.
- Koynov, V., I. Kabakchiev, K. Boneva. 1998. Atlas of the soils in Bulgaria. Zemizdat. p. 250. (in Bulgarian)
- Kutrovskiy, M. A., V. F. Val'Kov. 2006. The Peculiarities of Rendzina Genesis. In The 18th World Congress of Soil Science.
- Kyrylchuk, A. 2017. Geographic and bio-lithogenic features of genesis and dissemination of rendzinas in the Western Ukrainian region. Scientific Papers Series-Management, Economic Engineering in Agriculture and Rural Development, 17(1), 265-272.
- Malinova, L. 2010. Soil Science and Soil Pollution. Publishing House at the University of Forestry. Sofia. ISBN 978-954-332-070-7. p. 236. (in Bulgarian)
- Marschner, H. 2011. Marschner's mineral nutrition of higher plants. Academic press. p. 645.
- Paganová, V. 2007. Ecology and distribution of *Sorbus torminalis* (L.) Crantz. in Slovakia. Horticultural Science, 34, 138-151.
- Patterson, R. A. 1982. Description of a rendzina from warialda, new south wales. p. 31
- Penkov, M., V. Donovan, T. Boyadzhiev, T. Andonov, N. Ninov, M. Yolevski, G. Andonov, Sv. Gencheva. 1992. Classification and diagnostics of soils in Bulgaria in relation to land division. Zemizdat, Sofia, p. 151. (in Bulgarian)
- Petrova, R., S. Bogdanov. 2012. A manual for practical seminars in Soil science. ISBN: 978-954-2910176. Virtual library – University of Forestry. Sofia. p. 150. (in Bulgarian)
- Pushkarov, N. 1938. Forest soils in Bulgaria. Gorski pregled. Year XXIII, issue 3/4, pp. 89-104. (in Bulgarian)
- Radmanović, S. B., A. R. Đorđević, N. S. Nikolić. 2015a. Humification degree of Rendzina soil humic acids influenced by carbonate leaching and land use. Journal of Agricultural Sciences, Belgrade, 60(4), 443-453.
- Radmanović, S. C., A. Đorđević, N. Nikolić. 2015b. Influence of environmental conditions on carbon and nitrogen content in Serbian Rendzina soils. Archive for technical sciences, 1(12).
- Teoharov, M., T. Shishkov, B. Hristov, E. Filcheva, R. Ilieva, I. Lyubenova, I. Kirilov, G. Dimitrov, V. Krasteva, B. Georgiev, M. Banov, P. Ivanov, M. Hristova, Z. Mitreva. 2015. Chernozems in Bulgaria - systematics, specific features and problems.

Chernozems in Bulgaria. Problems, assessment, use and protection. Scientific papers, pp. 20-34. (in Bulgarian)

Tümsavaş, Z., E. Aksoy. 2008. Some properties and nutrient element contents of the soils in Bursa province Rendzina Great Soil Group. Journal of Agricultural Faculty of Uludağ University (Turkey).

Venturella, G. 2004. Climatic and pedological features of Sicily. *Bocconea*, 17, 47-53. World Soil Resources Reports No. 106. FAO, Rome.

Zahariev, B. 1979. Forest vegetation zoning of the People's Republic of Bulgaria. Zemizdat. p. 195. (in Bulgarian)

ISO 11277: Soil quality – Determination of particle size distribution in mineral soil material – Method by sieving and sedimentation (ISO 11277:1998+ ISO 11277:1998 Corrigendum 1:2002)

NEN-ISO 10693. 2004. Soil quality. Determination of carbonate content. Volumetric method. www.nen.nl.



Forms and Distribution of Potassium in Red Laterite Soils of Patigi in North Central Nigeria

Idris A.D., Olaniyan J.O., Affinnih K.O. and Ajala O.N

Department of Agronomy, Faculty of Agriculture, University of Ilorin, Ilorin, Nigeria
P.M.B 1515

Corresponding Author: Ajala O.N, e-mail: segnathorg@gmail.com



Abstract

The study evaluated the forms and distributions of potassium in red laterite soils. Top soils samples 0 – 30cm, were randomly collected from thirty different major agricultural areas across Patigi LGA of Kwara State. Descriptive statistics was performed while regression analysis was used to assess the correlation between potassium forms. Results showed the exchangeable sodium (Na^+) was very low to moderate. The values ranged from 0.00 – 0.27 cmol/kg soil. The exchangeable potassium (K^+) of the soils is very low with values of 0.11 – 0.30 cmol/kg. Calcium (Ca^{2+}) values ranged between 0.10 and 5.1 cmol/kg soil while magnesium (Mg^{2+}) ranged from 0.1 – 2.9 cmol/kg soil. The total potassium (K) obtained by concentrated perchloric acid (HClO_4) had higher values (3.1 – 11.0 cmol/kg of soil) than other potassium types studied. The available potassium (K) was positively and significantly correlated with HCl Extractable K^+ ($r = 0.98$); HNO_3 Extractable K^+ ($r = 0.93$) and HClO_4 Extractable K^+ ($r = 0.90$) at $P < 0.01$. The values of the extractable potassium increased in the order of $\text{NH}_4\text{OAc} < \text{HCl} < \text{HNO}_3 < \text{HClO}_4$. The study revealed that Patigi soils are quite low in available K^+ content thus, the supplying power of potassium in these soils is low, hence the need for potassium fertilization for a sustainable crop production.

Keywords: Forms, Distribution, Potassium, Red laterite soils, Patigi.

Introduction

Potassium (K) is considered an important element in soils. This essential nutrient is perceived to be next to nitrogen (N) in terms of plant nutrient requirements and is strongly involved in assimilation, phloem loading and transportation through xylem Mengel and Kirkby, (2001). Plants require potassium for a number of functions vis a vis; translocation of sugars, starch production in grains, nitrogen fixation in legumes and protein synthesis. It has been reported that K has a role in the process of folding and unfolding of stomata and in regulation of guard cells' osmotic activities (Dietrich et al., 2001). Furthermore, K also influences enzymatic processes and ATP synthesis. For this reason, plants suffering from K deficiencies are strongly affected by droughts. In addition, one key beneficial property of K in plants is its high tolerance of low temperatures leading to an improved protection against frost injury and winterkill (Wang et al., 2013).

Potassium positively affects disease resistance of crops (Oborn *et al.*, 2005). It has been reported to have an important role in N₂-fixing legumes such as red clover. Also, adequate sward legume content was achieved when the legumes have sufficient plant-available K during the growing season Romer and Lehne (2004). This is because N₂ -fixing bacteria need an ample supply of potassium for efficient functioning (Johnston, 2003).

Over the years, crop yields have not been commensurate with the level of soil inputs in Patigi LGA probably because of inherent factors relating to soil nutrients especially potassium deficiency in the area among other constraints. This could be attributed to an overestimation of plant-available K as the solution K obtained from the most widely used method of extracting K can be easily leached and unavailable during wet period for plant uptake (Carrow *et al.*, 2001).

Various extractants (dilute mineral acids, exchangeable K and dilute CaCl₂) (Mohammed, 2006) have been used in Kwara State soils, with the hot N HNO₃ the most effective compared with the neutral (pH 7.0) 1M NH₄OAc (ammonium acetate) which is the most widely used for extracting K.

The choice of extractant employed, however, is established from correlation between amounts extracted and crop growth/ yield (Affinnih *et al.*, 2014). While the former removes exchangeable K on soil CEC sites as well as solution K, the latter would also replenish non exchangeable K from the exchange sites. In spite of the higher correlation value which gives a better assessment of plant available soil K especially in soils with high total salts (Affinnih *et al.*, 2014, Ogunwale and Mohammed, 2006) from hot HNO₃, research on solution and exchangeable K replenished by nonexchangeable K is scarce. Therefore, the main objective of this study is to assess the distribution of total and available potassium in red laterite soils of Patigi in North Central Nigeria.

Materials and Methods

The study location

The study location: The study was conducted at the Agronomy Department Laboratory, Faculty of agriculture, University of Ilorin, Ilorin, Nigeria. Soil samples were collected in Patigi LGA of Kwara State, North Central Nigeria.

The area (2925sq.km) which has about 5% of total land area of the State, is located between latitude 8.50 and 9.00 North and longitude 5.60 and 6.00 East. Humid climate prevails which is characterized by wet and dry seasons, each lasting for about six months. Total annual rainfall is between 800 and 1200 mm while the temperature is between 30°C and 35°C.

Table I. Showing GPS coordinates of the agricultural villages used for this investigation

S/N	NAME OF TOWN/ VILLAGE	DISTRICT LATITUDE	GPS COORDINATES LONGITUDE	
1	Esanti	Lade	8° 44' 11"	5° 28' 48"
2	Lata Nna	Lade	8° 41' 01"	5° 28' 26"
3	Sunkusu	Lade	8° 47' 56"	5° 43' 33"
4	Gada Maagin	Lade	8° 35' 58"	5° 39' 44"
5	Ndanaku	Lade	8° 34' 50"	5° 30' 16"
6	Sakpefu	Lade	8° 49' 00"	5° 36' 04"
7	Rani Ndako	Lade	8° 45' 31"	5° 39' 16"
8	Chenegi	Lade	8° 48' 44"	5° 35' 47"
9	Lade	Lade	8° 45' 32"	5° 37' 01"
10	Lalagi	Lade	8° 49' 51"	5° 31' 10"
11	Likofu	Patigi	8° 43' 24"	5° 42' 53"
12	Patigi	Patigi	8° 43' 29"	5° 45' 18"
13	Gbaradog	Patigi	8° 44' 15"	5° 45' 14"
14	Gbadokin	Patigi	8° 43' 31"	5° 47' 45"
15	Ragada	Patigi	8° 43' 39"	5° 43' 04"
16	Godewa	Patigi	8° 44' 38"	5° 44' 09"
17	Tswatagi	Patigi	8° 39' 36"	5° 47' 39"
18	Ellah	Patigi	8° 46' 32"	5° 45' 10"
19	Mawogi	Patigi	8° 44' 28"	5° 50' 41"
20	Esungi	Patigi	8° 43' 40"	5° 48' 09"
21	Mamba	Kpada	8° 36' 48"	5° 56' 08"
22	Rogun	Kpada	8° 38' 49"	5° 55' 13"
23	Egboro	Kpada	8° 31' 32"	5° 41' 58"
24	Zhituala	Kpada	8° 37' 21"	5° 48' 23"
25	Kpada	Kpada	8° 44' 31"	5° 28' 48"
26	Gulugi	Kpada	8° 44' 03"	5° 46' 35"
27	Echiwada	Kpada	8° 42' 01"	5° 56' 36"
28	Gakpan	Kpada	8° 41' 32"	5° 38' 58"
29	Koro	Kpada	8° 08' 42"	5° 30' 39"
30	Kusogi	Kpada	8° 43' 02"	5° 42' 47"

Soil sampling and processing

Top soils, 0-30cm, from thirty agricultural areas of Patigi LGA were randomly sampled using soil auger. Twenty auger borings were collected from each area to form the composite

sample. The samples were air dried for 3 days, ground, sieved and stored in labeled bags for laboratory analysis.

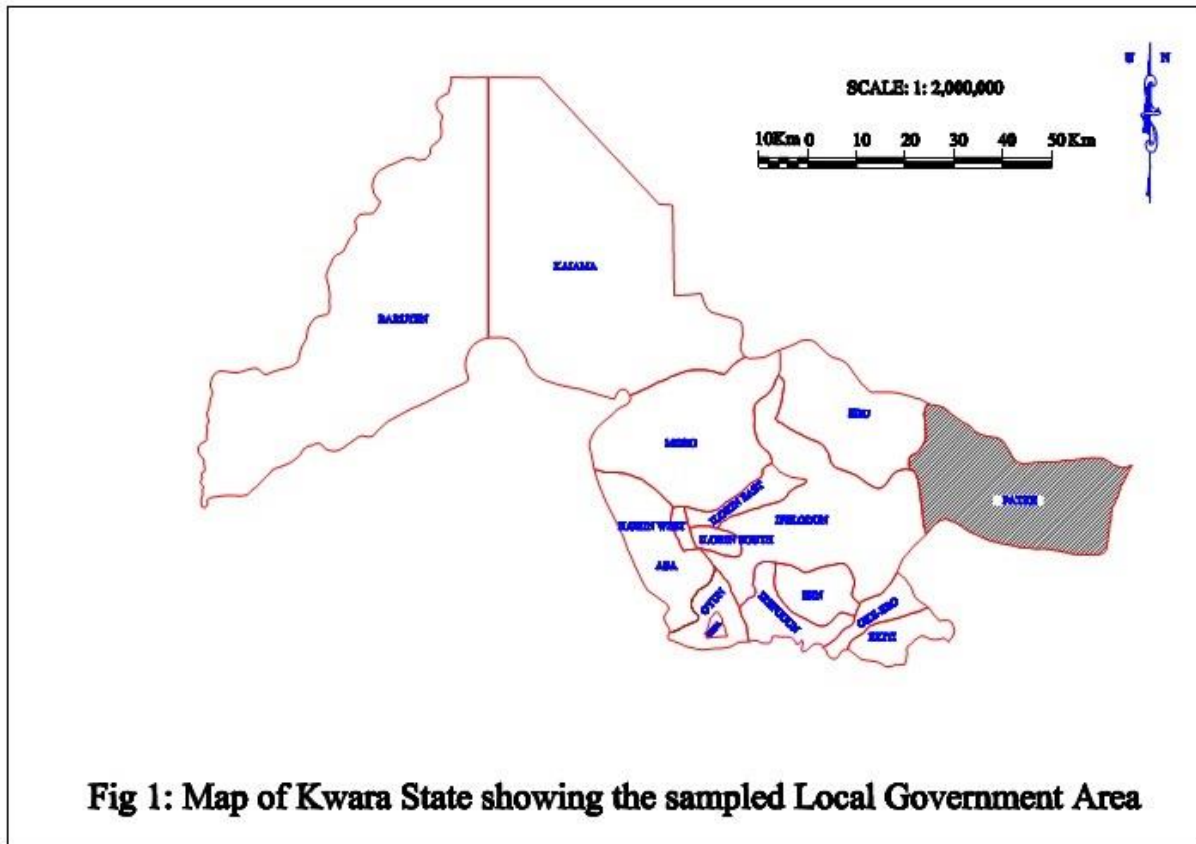


Figure 1. Map of Kwara State showing the sampled Local Government Area (Patigi)

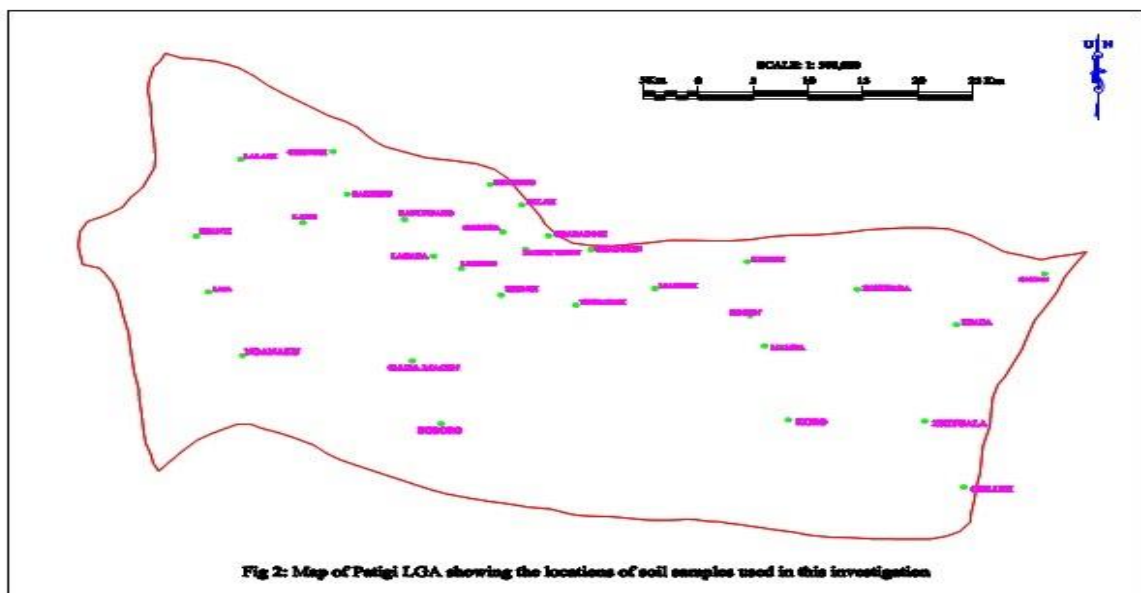


Figure 2. Map of Patigi LGA showing the locations of soil samples used in this investigation

Basic exchangeable cations determination

A 5g of representative sample was weighed into sample bottle containing 50ml of 1N neutral ammonium acetate NH_4OAc solution. The mixture was shaken for 1 hour after that the content of the bottle was left to equilibrate overnight. Afterward the content was filtered through a Whatman No 42 filter paper into another bottle (Walkley and Black; Jackson 1973). The filtrate was used for the determinations of Na^+ and K^+ by flame photometry, while Ca^{2+} and Mg^{2+} combination were verified by versenate titration method using Erichrome black T as the indicator. Ca^{2+} alone was determined by versenate titration method using calcon as the indicator. The concentration of the cations were calculated after due note of the dilution factors and expressed in cmol. kg^{-1} soil (Walkley and Black; Jackson 1973).

Determination of calcium and magnesium (Ca+Mg)

A 5ml of the extract was pipetted into a 100ml capacity conical flask, then 5ml of concentrated ammonium hydroxide NH_4OH , 5 drops of 10% hydroxylamine hydrochloride, 5 drops of 5% sodium cyanide and 3 drops of Erichrome black T indicator added. This was titrated against 0.02N EDTA. Colour change was observed from colorless to blue at the end point (Walkley and Black, Jackson 1973).

Determination of calcium (Ca)

A 5ml of the extract was pipetted into a 100ml capacity conical flask. 5ml of 20% sodium hydroxide (NaOH) was added and thereafter the following indicators were added; 5 drops of 10% hydroxylamine hydrochloride; 5 drops of 5% sodium cyanide and 3 drops of calcon. The mixture was titrated against 0.02N EDTA. At the end point, the colour changed from pink to light blue (Walkley and Black, Jackson 1973).

Calculation:

Determination of Na and K

The exchangeable Na^+ and K^+ were determined by flame photometry using soil extracts. The standards of Na^+ and K^+ were prepared with concentrations in parts per million (ppm).

Determination of acid extractable K^+

Potassium was extracted from soil sample using three extracting solutions: 1N hydrochloric acid (HCl); 1N nitric acid (HNO_3); and concentrated perchloric acid (HClO_4) which were used to extract the total form of potassium (Wood, De Turk 1941).

Nitric acid extractable K^+

The Nitric acid and K were performed according to Hanway and Heidel (1952). The standards of the K^+ was prepared in (ppm) for the nitric acid soluble potassium. The intensities of flame emission for potassium standards were recorded and plotted against their various concentrations in (ppm) the intensity of flame emission for each of the extracts was also recorded. The concentrations K^+ in the nitric acid extracts were determined from the

graph of standards using their flame emission intensities Hanway and Heidel (1952). The differences between the value obtained and that of exchangeable K^+ is termed fixed K.

Hydrochloric acid extractable K^+

The hydrochloric acid extractable K^+ was performed according to Bouyoucos (1962)

Perchloric acid extractable potassium (Total K)

According to Jackson (1973) the total potassium in the studied soil was investigated

Statistical Analysis

Descriptive statistics were determined for each soil parameters using SPSS software. Correlation analysis procedure of SPSS was used to assess the relationship between the analyzed parameters.

Results and Discussion

The range values of exchangeable cations of Patigi surface soil is presented in Table 1. The Exchangeable Na^+ of the analyzed soils was very low to moderate. The values ranged from 0.00 – 0.27 cmol/kg of soil. Na^+ saturation percentage greater than one can cause soil quality problems and interfere with normal plant growth. Apart from being poisonous to roots, it can limit water movement and restricting root growth (Annon 2004). The exchangeable K^+ of the soils are very low with values of 0.11 – 0.30 cmol/kg. This is consistent with the report by Ajiboye and Ogunwale (2008) who observed the range of 0.11 - 0.20 cmol/kg in the clay fraction of the surface soils of Ejigba, Kogi State, Nigeria. In addition, Ndukwu et al. (2012) reported a mean value of 0.11 and 0.10 in Nkwoagu soils of Abia State, Nigeria, respectively. These values are lower than those obtained in the present study. The authors, however, observed higher value of 0.45 cmol/kg in Bendel soils of the State.

Unamba-Oparah, (1985) and Ano, Okeke (1987) have reported that soils having exchangeable K^+ values higher than 0.4 cmol/kg are regarded as better endowed with this form of K^+ . The lower values recorded for exchangeable K^+ in this study might be due to depletion arising from continuous cropping activities as known for soils of this part of Nigeria. Reported values of exchangeable K varied widely across the different ecologies of the country. These values ranged between 0.04 and 0.34 cmol/kg for some Nigerian soils in the savanna region (Wild 1971); 0.03 to 0.33 cmol/kg for some Eastern Nigeria soils (Ekpete 1972) and 0.08 to 1.18 cmol/kg for Southern guinea savanna and rainforest agro-ecologies Udo and Ogunwale (1978).

According to Adepetu and Sobulo (1987), the availability of K in soils is a function of Exchangeable K^+ content of the soil. Thus, the exchangeable K is the amount of K which is available for plant use (Yagodin 1984). Calcium values in the surface soils ranged from 0.10 – 5.1 cmol/kg of soil while that of Magnesium ranged from 0.1 – 2.9 cmol/kg of soil. The values for both Na and K are comparatively lower to those of Ca and Mg in the surface soils. The low K: Ca or K: Ca + Mg could hinder K uptake in these soils. Wild (1971) reported a leaching of K in New Zealand soil due to dislodgement of K by Ca owing to selective

absorption process of Ca. Ekpete (1972) also recorded a reduced K uptake by plants in soils containing a high concentration of soluble Ca.

Table 1. Range of exchangeable Cations in Patigi Surface Soils

Ranking N	Exch Na ⁺ (cmol/kg of soil)	N	Exch K ⁺ (cmol/kg of soil)	N	Excha Ca ²⁺ (cmol/kg of soil)	N	Exch Mg ²⁺ (cmol/kg of soil)
V low 3	0.00 – 0.06	9	0.11 – 0.20	25	0.10 – 1.90	4	0.1 – 0.9
Low 14	0.07 – 0.13	13	0.21 – 0.30	5	2.00 – 2.90	10	1.0 – 1.9
Moderate 13	0.14 – 0.20	7	0.31 – 0.40	-	3.00 – 3.90	4	2.0 – 2.9
High -	0.21 – 0.27	1	0.41 – 0.50	-	4.00 -5.10	12	3.0 – 3.9

Exch= Exchangeable, N= Number of samples

The Extractable K⁺ in 1N HCl and in 1N HNO₃ was higher than NH₄OAc exchangeable K⁺ (Table 2). It could be that, more of this K⁺ is contained in forms which are soluble in these acids than in NH₄OAc solution. Also, the HNO₃ extractable K⁺ was observed to be higher than the HCl extractable K⁺. The mobile K-reserve determined by 1N HNO₃ extractant was higher in all the soils than the corresponding K-reserve assessed by 1N HCl extractant.

Table 2. Range of Acid Extractable Potassium in Patigi Surface Soils

Ranking N	HCl Extract K ⁺ (cmol/kg of soil)	N	HNO ₃ Extract K ⁺ (cmol/kg of soil)	N	HClO ₄ Extract K ⁺ (cmol/kg of soil)
V Low 14	1.5 – 2.0	5	1.5 – 2.5	5	3.1 – 5.0
Low 11	2.1 – 2.6	16	2.6 – 3.6	22	5.1 – 7.0
Moderate 2	2.7 – 3.2	7	3.7 – 4.7	1	7.1 – 9.0
High 3	3.3 – 3.8	2	4.8 – 5.8	2	9.1 -11.0

Extrac= Extractable, N= Number of samples

The total potassium (K) verified by concentrated perchloric acid (HClO₄) indicated higher values than other forms of K in the soils. The total K usually reflects the nature and degree of weathering of the parent materials.

The high value for total K in the studied soils may be as a result of the present of K bearing minerals like feldspars and mild weathering associated with it, as well as low rainfall regime of study areas. This assertion is supported by (Udo, Ogunwale 1978).



Figure 3. Map of Patigi LGA showing the available K in the studied areas

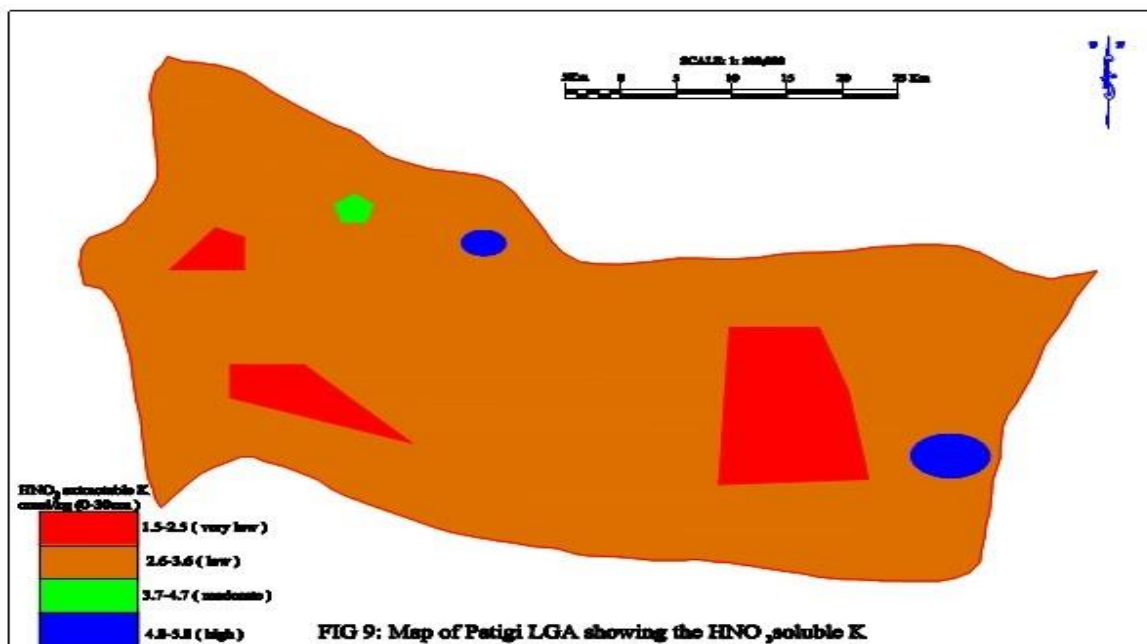


Figure 4. Map of Patigi LGA showing the HNO₃ soluble K of the studied areas

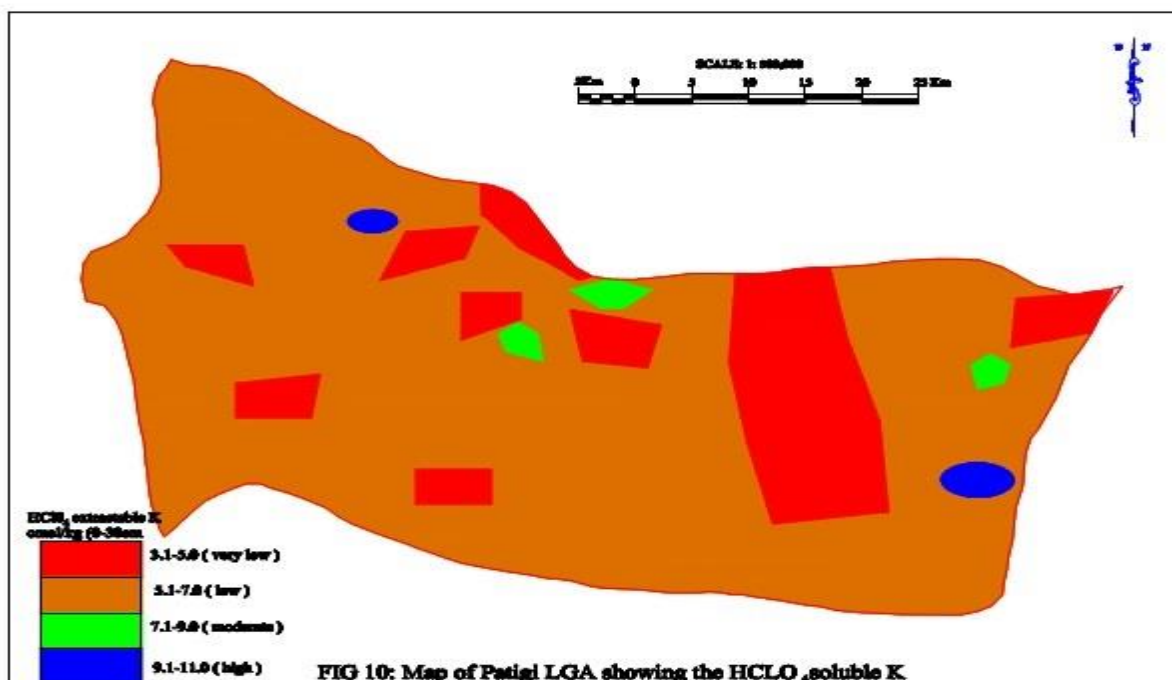


Fig 5: Map of Patigi LGA showing the HClO₄ soluble K of the studied areas

Table 3: Correlation between Forms of Potassium, pH, Organic Matter and Exchangeable Bases

	Exch Ca ²⁺	Exch Mg ²⁺	Exch Na ⁺	Avail K ⁺	HCL Ext K	HNO ₃ Ext K	HClO ₄ Ext K
Exch Ca	-	0.93**	0.06	-0.09	-0.08	-0.07	-0.02
Exch Mg		-	0.15	-0.06	-0.06	-0.03	0.01
Exch Na			-	0.15	0.11	0.16	0.17
Avail K				-	0.98**	0.93**	0.90**
HCL Ext K					-	0.95**	0.91**
HNO ₃ Ext K						-	0.97**
HClO ₄ Ext K							-

** P<0.01, Exch= Exchangeable, Avail= Available, Ext= Extractable

Table 3 shows the correlation coefficients of the linear regression between soil K forms. Available K correlated positively and significantly ($P < 0.01$) with HCl Extractable K⁺ ($r = 0.98$); HNO₃ Extractable K⁺ ($r=0.93$) and the HClO₄ Extractable K⁺ ($r=0.90$) at 0.01 probability level. This is consistent with findings of Nabiollahy et al. (2006), Padol and Mahajan (2003), and Sharpley (1989). It is also agreement with the finding of Najafi Ghiri et al. (2010) who reported correlation value of $r = 0.88$, 0.96 and 0.83 between exchangeable K⁺ and HNO₃Extractable K⁺, for three different groups of Iranian soil, respectively. The

findings in this study imply that the availability of K in soils is a function of Exchangeable K^+ content in the soil, thus, an increase in any one will lead to an increase in the other. Similar observation was made by Adepetu and Sobulo (1987), that the accessibility of K in soils is a function of Exchangeable K^+ content of the soil.

Conclusion

The surface soils in Patigi LGA are generally low in exchangeable K^+ . The values of the extractable K^+ increased in the order of $NH_4OAC < HCl < HNO_3 < HClO_4$. K forms correlated positively and significantly among each other, thus an increase in one form will lead to a corresponding increase in the other.

References

- Adepetu, J. A. and R. A. Sobulo. 1987. Soil testing and fertilizer formulation for crops production in Nigeria. A paper presented at the national fertilizer
- Affinnih, K. O., I. S. Salawu, and A. S. Isah. Methods of available potassium assessment in selected soils of Kwara State, Nigeria. *Agrosearch J.* 14 (1): 76–87.
- Ajiboye, G.A. and J.A. Ogunwale. 2008. Potassium Distribution in the Sand, Silt and Clay Separates of Soils Developed over Talc at Ejiba, Kogi State, Nigeria. *World Journal of Agricultural Sciences* 4 (6): 709-716.
- Annon. 2004. Cation – Exchange Capacity (CEC), Soil Properties and Nutrition Information, Tree Fruit Research and Extension Centre, Washington State University, 1100 N Western Ave., Wenatchee, WA, 98801 USA, <http://soils.tfrec.wsu.edu/webnutritiongood/soilpro ps/04CEC.htm>.
- Ano, A.O. and J.E.Okeke. 1987. Fertilizer use economy in cassava production. Annual report, National Root Crops Research. Institute, Umudike, Umuahia, Nigeria.
- Bouyoucos, G.J. 1962. Hydrometer method improved for making particle-size analysis of soils. *Agro.J.*, 54: 464-65.
- Carrow, R. N., D. V. Waddington, and P. E. Rieke. 2001. Turfgrass soil fertility and chemical problems: Assessment and management. <https://books.google.com>. Retrieved 22nd June, 2017
- Dietrich, P., D. Sanders, and R. Hedrich. 2001. The role of ion channels in light-dependent stomatal opening. *J. Exptl. Bot.* 52(363) : 1959-1967.
- Ekpete, D.M. 1972. Predicting responses of potassium for soils of Eastern Nigeria. *Geodrama*, 8: 178-189.
- Forde, C.M. 1966. Potassium Supplying Power of Soils in Southern Eastern Nigeria. Quarterly Progress Report Nigeria Inst. Of oil palm Res. 57, 21-22.
- Hanway, J. and H. Heidel. 1952. Soil analysis methods as used in Iowa State College Soil Testing Laboratory. *Iowa State College Agri. Bull.*, 57: 1-13.
- Jackson, M.L. 1973. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi J. Crop and Weed, 10(2)
- Johnston E.A. 2003. Understanding potassium and its use in agriculture. European Fertiliser Manufacturers 'Association. Brussels 40pp. European Fertiliser Manufacturers Association, Avenue E. Van Nieuwenhuysse 4, B-1160 Brussels, Belgium. Available: <http://www.efma.org/> 2008.

Jones, S.U. 1982. Fertilizers and soil fertility. Reston Publishing Company, Inc., U.S.A., pp.190-192.

Kwara State Agricultural Development Project (KWADP) 2007. Ilorin, Nigeria.
Mengel, K. and E. A. Kirkby. 2001. Principles of Plant Nutrition. 5th edition. Springer. pp. 849.

Mohammed, K. O. 2006. Evaluation of soil extractants for available potassium by sorghum in selected soils in southern Guinea savanna of Nigeria. J. vocational and technical studies 6 (1): 124-132.

Nabiollahy, K., F. Khormali, K. Bazargan, and Sh. Ayoubi. 2006. Forms of K as a function of clay mineralogy and soil development. Clay Miner., 41: 739-749.

Najafi Ghiri, M., Abtahi, A., Jaberian, F. and Owliaie, H.R. 2010 Relationship between Soil Potassium Forms and Mineralogy in Highly Calcareous Soils of Southern Iran. Australian Journal of Basic and Applied Sciences, 4(3): 434-441.

Ndukwu, B. N., M. C. Chukwuma, C. M. Idigbor, and S. N. Obasi, 2012. Forms and distribution of potassium in soils underlain by three lithologies southeastern Nigeria. International Journal of Agric. and Rural development. 15 (2): 1104 – 1108.

Oborn I., Y. Andrist-Rangel, M. Askegaard, CA. Grant, CA. Watson, AC. Edwards. 2005. Critical aspects of potassium management in agricultural systems. Soil use and Management. 21. 102-112.

Ogunwale, J. O. and K. O. Mohammed. 2006. Potassium quantity-intensity relations and uptake by Sorghum bicolor (L) Moench, in some selected soils of Kwara State, Nigeria. J. Arid Agric. 16: 121-127.

Padol, V.R. and S.B. Mahajan. 2003. Status and release behaviour of potassium in some swell-shrink soils of Vidarbha, Maharashtra. J. of Maharashtra Agricultural Universities, 28(1): 3-7

Prince, R. 2008. Plant Nutrients, North Carolina Department of Agriculture and Consumer Services. <http://www.ncagr.gov/cyber/kidswrld/plant/nutrient.htm>,

Romer, W. and P. Lehne. 2004. Neglected P and K fertilization in organic farming reduces N₂ fixation and grain yield in a red clover-oat rotation. Journal of Plant Nutrition and Soil Science. 167:106-113.

Sharpley, A.N. 1989. Relationship between potassium forms and mineralogy, Soil potassium forms. Sci. Soc. Am. J., 52: 1023-1028.

Udo, E.J. and J.A. Ogunwale. 1978. Forms and distribution of Potassium in selected Nigerian Soils. Nigeria. J. Soil Sci., 12 (1 and 2): 215-232.

Unamba-Oparah, I. 1985. The potassium status of sandy soils of Northern Imo State, Nigeria. Soil Sciences. 139 (5): 437- 445.

Wang, M., Q. Zheng, Q. Shen, and S. Guo, 2013. The critical role of potassium in plant stress response. Int. J. Mol. Sci. 14 (4)a: 7370-7390.

Wild, A.A. 1971. The potassium status of soils in the savanna zone of Nigeria. Expl. Agric., 7: 257-270.

Wood, L.K. and E.E. De Turk. 1941. The absorption of potassium in soils in non-replaceable forms. Soil Sci. Soc. America Proc., 5: 152-61.

Yagodin, B.A. 1984. Agricultural Chemistry 2pub: MIR publisher Moscow 7- 37



Utilization of biochar in improving yield of wheat in Bangladesh

Md Toufiq Iqbal

Department of Agronomy and Agricultural Extension

University of Rajshahi

Rajshahi 6205, Bangladesh

Corresponding Author: Md Toufiq Iqbal, e-mail: toufiq_iqbal@yahoo.com



Abstract

Biochar is a carbon-rich co-product resulting from pyrolysis process. Biochar amendment to soil can improve productivity of wheat plant. Therefore, the utilization of biochar in improving yield of wheat in Bangladesh was investigated in this study. Soil pH decreased 0.8 units and organic matter increased 0.67% after 159 days of incubation for the biochar amendment. Several yield parameters was similar between Bangladesh Agricultural Research Council (BARC) recommended fertilizer and half of BARC recommended fertilizer plus rice straw added treatment. This study also found that the combination of rice straw biochar with half of BARC recommended fertilizer gave better effect than single application rice straw biochar as well as gave the highest yield of wheat in the same treatment. Rice straw biochar can have the potential to decrease dependence on chemical fertilizer for wheat production. Therefore, utilization of biochar is a viable option to improve yield of wheat in Bangladesh.

Key words: Rice straw biochar, Pyrolysis, charcoal, BARI Gom 28

Introduction

“Biochar” is a relatively new term, yet it is not a new substance (Skjemstad *et. al.*, 2002). Historical use of biochar dates back at least 2000 years (O'Neill *et. al.*, 2009). Biochar is created by heating organic material under conditions of limited or no oxygen (Lehmann 2007). The relatively long residence times (usually hours) promotes extensive secondary reactions within biochar particles and in the gas and vapour phases, leading to condensation (Sohi *et. al.*, 2010). Several researches showed that biochar has contents of carbon (C), nitrogen (N), phosphorus (P) potassium (K) and other essential macro and micronutrients depending on types of biochar (Chan and Xu 2009).

Biochar can increase microbial activity and reduce nutrient losses during composting (Dias *et. al.*, 2010). Biochar can help to supply P to many agricultural crops (Solaiman *et. al.*, 2010). The application of biochar may contribute to the nutrient uptake but the effect of biochar could be either positive or negative depending on soil characteristics and other soil microorganisms (Hammer *et. al.*, 2014). Compared to other soil amendments, the high surface area and porosity of biochar enable it to adsorb or retain nutrients and water and also provide a habitat for beneficial microorganisms to flourish (Glaser *et. al.*, 2002, Lehmann and Rondon 2006, Warnock *et. al.*, 2007).

A field study showed that biochar amendment improves soil fertility and productivity of mulberry plant in Bangladesh (Ahmed *et. al.*, 2017). However, the utilization of biochar in improving yield of wheat in Bangladesh was not investigated under pot experiment. This

study aims at the following objectives: (i) To quantify changes in soil physical and chemical properties on biochar amended incubated soil (ii) To investigate growth and yield of wheat grown on biochar amended incubated soil. It was hypothesized that growth and yield of wheat will be better in biochar amended incubated soil than other treatments. Likewise, soil nutrient availability will be increased due to biochar amendment.

Materials and Methods

2.1 Soil

The soil was collected from the Rajshahi region which is located at 26th AEZs (Agro-ecological Zone) of Bangladesh named High Barind Tract. The texture of the soil was clayey. The organic matter status and soil fertility was low and the pH of the soil was in between 6.8-7.9 (Bhuiya *et. al.*, 2008). The experimental soil was collected from the Agronomy Farm, University of Rajshahi, Bangladesh. The soil was collected from cultivable plot in which tomato was grown before soil collection. The collected soil initial basic physical and chemical properties shown in Table 1.

Table 1. Initial soil basic physical properties and nutrient contents

Soil pH	OM (%)	TN (%)	P (ppm)	K (me/100g)	S (ppm)	Zn (ppm)	Ca (me/100g)	Mg (me/100g)	Cu (ppm)	Fe (ppm)	B (ppm)	Mn (ppm)
8.3	1.39	0.08	12.5	0.16	14.4	0.66	15.63	1.89	1.26	27.3	0.50	13.7

2.2 Chemical properties of biochar used in this study

Chemical properties of biochar vary widely, depending on the source of biomass used and the conditions of production of biochar (Lehman and Joseph, 2009). In this experiment two types of biochar like rice straw and compound biochar were used (Fig. 1 and Fig. 2). The chemical properties of biochar are given Table 2.

Table 2. Chemical properties or ingredients or composition of biochar used in this experiment

Element evaluated	Rice straw biochar	Compound biochar
pH	8.02	8.87
Total N (%)	1.73	2.05
Olsen-P (mg/kg)	33	49
Total K (%)	0.2	1.1
OC (g/kg)	54	67
Total Na (%)	0.22	0.63
S (mg/kg)	0.18	0.35
Fe (mg/kg)	7.79	8.71
Ca (mg/kg)	213	273
Cu (mg/kg)	0.06	0.09
Al (mg/kg)	0.88	0.99
Mn (mg/kg)	4.37	5.13
Si (%)	0.01	0.13
Ash (%)	50.35	39.67



Figure 1. Pictorial view of compound biochar used in this experiment



Figure 2. Pictorial view of rice straw biochar used in this experiment

2.3 Plant and seed germination technique

The recently released Bangladesh Agricultural Research Institute (BARI) wheat variety BARI Gom 28 was used as a testing plant. The pedigree of BARI Gom 28 is shown in Table 3. The yield performance of BARI Gom 28 is best among all recently BARI released wheat varieties in Rajshahi region of Bangladesh. For that reason, the BARI Gom 28 has been selected in this study. Seeds were soaked for 30 h in de-ionized water. After that it was covered with cloth for sprouting that helps to maintain optimum temperature. Seed was sprouted after 48 h.

2.4 Experimental design

The basic objectives of this study were twofold: (a) To quantify changes in soil chemical properties due to addition of biochar within soil. (b) Growth and yield of wheat was investigated on the biochar added incubated soil as a pot experiment. Two types of biochar like rice straw and compound biochar were used. The chemical properties or nutrient compositions or ingredients of both biochar was already shown in Table 2. The treatments were replicated three times and laid out in Randomized Complete Block Design (RCBD) for the pot experiment.

2.5 Soil incubation experiment

Both rice straw and compound biochar was mixed with collected soil samples. Both biochar was grinded separately before mixing with collected soil samples. The amount of rice straw biochar was incorporated 16.67 g/kg soil. Likewise, the amount of compound biochar was incorporated 66.67 g/kg soil. After biochar incorporation, soil incubation study was conducted in the laboratory to study the changes in soil physical and chemical properties due to biochar amendment within soil. Biochar amended soils were kept in six separate transparent plastic containers for two containers each like control, rich husk biochar and mineral enriched biochar during incubation experiment. Soil and biochar were mixed by agitating each container every alternative day during whole incubation period. The unamended control was also subject to disruption of mixing. Water was maintained to field capacity. Soil water was monitored by a soil moisture meter (PMS-714; Made in Taiwan) during incubation period. Maximum and minimum temperature as well as relative humidity was recorded during soil incubation experiment by a temperature humidity meter. The incubation time was 159 d in total, and soils were analyzed at 0 d, 62 d and 159 d to determine their changes in physical and chemical properties due to biochar amendment.

Table 3. Pedigree of BARI Gom 28

Variety	Accession No.	Pedigree/ Cross	Year of Release
BARI Gom 28	BAW 1141	CHIL/2*STAR/4/BOW/CROW//BUC/PVN/3/2*VEE#10 CMSS95Y00624S-0100Y-0200M-17Y-010M-5Y-0M	2012

Source: Raj et. al. (2012)

2.6 Fertilizer additions

Incubated soils were divided in separate plastic bags for 1 kg soils each. Several small fertilizer doses were added in separate plastic bags that contains 1 kg soil each for treatments T₂, T₅ and T₆ respectively according to BARC recommended fertilizer doses for wheat production in Bangladesh. Fertilizer was added according to initial soil basic physical and chemical properties. Magnesium was not added to the incubated soil due to its availability to the initial soil. Amount of fertilizer reduced to half for the half BARC recommended fertilizer treatment. The amount of fertilizer mixed within incubated soil is shown in Table 4.

Table 4. Amount of BARC recommended fertilizer added in each pot

Fertilizer name	Amount added
Urea	135.24 mg/kg soil
Triple super phosphate (TSP)	19.76 mg/kg soil
Murate of potash (MP)	16.67 mg/kg soil
Gypsum (CaSO ₄)	12.35 mg/kg soil
Zinc Sulphate (ZnSO ₄)	5.8 mg/kg soil
Boric acid (H ₃ BO ₃)	0.124 mg/kg soil
Magnesium Sulphate (MgSO ₄)	-*
Organic matter (Cowdung)	2.47 g/kg soil

*No Mg was added due to BARC recommended available Mg was found in the collected soil.

2.7 Treatments for pot experiment

The pot experiment was conducted in seven treatments with three replications. These are T₀: Control (nothing was added) T₁: Half of BARC recommended fertilizer for wheat production T₂: BARC recommended fertilizer for wheat production T₃: Rice straw biochar only T₄: Compound biochar only T₅: Half BARC recommended fertilizer for wheat production plus rice straw biochar T₆: Half BARC recommended fertilizer for wheat production plus compound biochar.

2.8 Pot experiment procedure

Pot was selected that contained about 1.25 kg soils each. The size of the pot was 17 cm × 17 cm × 8.5 cm. No opening was kept at the bottom of the each pot to protect leaching of nutrients from the pot. Soils were compacted properly in each pot during filling of biochar amended incubated soils and other treated incubated soils into several pots. To avoid contamination within the soil, different plastic jars and separate snap polythene bag were used for different treatments and replicated samples. Water was maintained to the field capacity for all soils through monitoring soil moisture by soil moisture meter (PMS-714; Made in Taiwan). Twelve uniform pre-germinated seeds were placed in each pot and covered by 0.5 cm of same treated soil from the top of pots. The pots were completely randomized and re-positioned regularly during spraying or watering to minimize any effect of uneven environmental factors during plant growth period. Plants were grown in a net house at the Department of Agronomy and Agricultural Extension, University of Rajshahi, Bangladesh.

2.9 Leaf area

The leaf area was measured with the help of Green Leaf Area Meter at 35 days after sowing (DAS). The specification of the green leaf area meter is Model: GA-5; Tokyo Photo electric Company Limited; Made in Japan. Two to five number of wheat plants was cut from the ground of the plant. Remaining seven numbers of plants were kept in each pot for other measurement. Harvested plants were cut into two pieces to set within the green leaf area meter. Leaf area of wheat plant was measured immediate after harvesting. After measurement

of leaf area shoot were dried in air for two days and then put in an oven for shoot dry weight measurement.

2.10 Plant harvest

Plants were harvested at maturity. Whole plants and roots with surrounding soils were removed from pots by gentle agitating of the pots to provide minimum disturbance to the roots and shoots. Intact plants were then lifted gently from the soil and shaken lightly to remove bulk soil from the roots. Whole plants including roots (after removal of bulk soil) were then placed in a snap polythene bag as well as kept 20-30 minutes for air-dry.

2.11 Measurements of soil chemical properties

The pH of the bulk soil was determined in deionized water using a soil-to-solution ratio of 1:5. Organic carbon of the bulk soil samples was determined by wet oxidation method (Walkley and Black, 1934). Bulk soil organic matter content was determined by multiplying the percent value of organic carbon with the conventional Van-Bemmelen's factor of 1.724 (Piper, 1950). The nitrogen content of the bulk soil sample was determined by distilling soil with alkaline potassium permanganate solution (Subbiah and Asija, 1956). The distillate was collected in 20 ml of 2% boric acid solution with methylred and bromocresol green indicator and titrated with 0.02 N sulphuric acid (H_2SO_4) (Podder *et. al.*, 2012). Bulk soil available S (ppm) was determined by calcium phosphate extraction method with a spectrophotometer at 535 nm (Petersen, 1996). The soil available K was extracted with 1N NH_4OAC and determined by an atomic absorption spectrometer (Biswas *et. al.*, 2012). The available P of the bulk soil was determined by spectrophotometer at a wavelength of 890 nm. The bulk soil sample was extracted by Olsen method with 0.5 M $NaHCO_3$ as outlined by Huq and Alam (2005). The Zn in the bulk soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA (Soltanpour and Schwab, 1997).

2.12 Data Collection

In the incubation experiment, changes in soil basic physical and chemical properties due to addition of two types of biochar for 0 d, 62 d and 159 d after biochar application were analyzed. The plant growth and yield data were collected during the pot experiment. Plant growth parameters like plant height, leaf area, tiller number, panicle length, spike length, spikelet per spike, shoot dry weight were recorded. Yield parameters like thousand grain weight, grain yield, straw yield and biological yield were recorded.

2.13 Statistical analysis

Results were analyzed by a one-way or two-way analysis of variance (ANOVA) using Genstat 12th edⁿ for Windows (Lawes Agricultural Trust, UK).

Results

3.1 Changes in soil pH and organic matter due to incubation after biochar amendment

Initial soil properties were changed with time during incubation (Table 5). Interestingly, soil pH declined due to biochar amendment in soil. In contrast, soil organic matter status was increased during incubation due to application of both compound and rice straw biochar. Thus, soil organic matter was significantly affected by biochar amendments.

Table 5. *Changes in soil pH and organic matter due to incubation*

Days of sampling	Soil pH in water		Soil organic matter (%)	
	Rice straw	Compound	Rice straw	Compound
0 days	8.3	8.3	1.4	1.4
62 days	8.2	7.4	1.62	1.79
159 days	8.0	7.5	1.89	2.07

3.2 Changes in soil macronutrients due to incubation after biochar amendment

Changes in soil macro nutrients status for the incubation experiment under biochar amendment is shown in Table 6. Interestingly, the nitrogen percentage increase with incubation time due to biochar amendment. In contrast, P content declined with incubation due to rice straw biochar amendment. However, P content initially reaches 335.10 ppm and then drop to 198.90 ppm in the compound biochar amended treatment. The potassium content of both rice husk and compound biochar was same and it increases with time. The magnesium content in both biochar increased with the increase of incubation time. The magnesium content increased about 2.5 times in rice straw and compound biochar after 159 days of incubation. On average, the calcium content did not change with incubation in both rice straw and compound biochar. The sulphur content dramatically increased in both type of biochar amendment due to incubation. This increasing trend was triple for rice straw biochar and twenty five times for compound biochar after 159 days of incubation.

Table 6. *Changes in soil macro nutrient status due to biochar amendment in incubation experiment*

Days of sampling	N in percent		P in ppm		K in me/100g		Ca in me/100g		Mg in me/100g		S in ppm	
	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound
0 days	0.08	0.08	29.80	29.80	0.31	0.31	15.53	15.53	2.43	2.43	36.1	36.1
62 days	0.09	0.10	23.17	335.10	1.10	1.10	15.72	12.97	5.01	5.93	54.9	780.1
159 days	0.10	0.12	7.90	198.90	1.11	1.11	15.89	13.73	8.13	8.76	94.3	907.3

3.3 Changes in soil micro nutrients due to incubation after biochar amendment

A change in soil micro nutrient status for biochar amendments due to incubation is shown in Table 7. On average, the zinc content within rice straw biochar amendment declined due to incubation. In contrast, zinc content reached double due to 159 days of incubation in compound biochar added treatment. Similarly, iron content declined due to incubation in rice straw biochar amendment. In contrast, iron content increased in compound biochar due to incubation of compound biochar. However, copper and manganese content in both rice straw and compound biochar did not change remarkably due to incubation. But, sulphur content increased in both rice straw and compound biochar due to incubation.

Table 7. *Changes in soil micro nutrient status due to biochar amendment in incubation experiment.*

Days of sampling	Zn in ppm		B in ppm		Fe in µg/g		Cu in µg/g		Mn in µg/g		S in µg/g	
	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound
0 days	0.51	0.51	0.62	0.62	12.9	21.1	0.79	0.75	8.8	72.7	34.9	780.1
62 days	0.31	0.74	0.40	4.94	7.4	22.3	0.76	0.78	10.2	75.7	35.9	785
159 days	0.40	1.09	0.81	3.03	6.2	24	0.72	0.79	10.5	79.4	40.2	790

3.4 Bulk soil nutrient contents, pH and organic matter

In general, nutrient contents did not change remarkably within bulk soil due to BARC recommended fertilizer and rice straw biochar application (Table 8). Interestingly, potassium content was found three times higher in rice straw biochar added treatment than control. Like as incubation, bulk soil pH declined in rice straw biochar added treatment. In contrast, bulk soil organic matter increased in rice straw biochar added treatment.

Table 8. *Bulk soil chemical properties and macro nutrient contents*

Treatments	Soil pH	Organic matter (%)	TN (%)	P (µg/g)	K (cmol ⁺ /kg)	Ca (cmol ⁺ /kg)	Mg (cmol ⁺ /kg)	S (µg/g)
Control	8.7	1.34	0.08	13.7	0.27	14.37	2.67	28.2
½ BARC	8.7	1.39	0.09	14.2	0.26	14.13	2.66	31.6
BARC	8.6	1.31	0.08	13.2	0.26	14.05	2.74	27.9
Rice straw	8.3	1.57	0.09	13.1	0.96	13.34	2.67	40.2
½ BARC + Rice straw	8.4	1.69	0.10	13.8	0.95	12.79	2.69	35.3

Bulk soil micro nutrient contents were shown in Table 9. Interestingly, iron and copper content declined in rice straw biochar added treatment than control. Other micro nutrient content like boron, zinc and manganese did not changed due to BARC recommended fertilizer and biochar application.

Table 9. *Bulk soil micro nutrient contents*

Treatments	B (µg/g)	Zn (µg/g)	Fe (µg/g)	Cu (µg/g)	Mn (µg/g)
Control	1.16	0.64	11.9	0.78	10.0
½ BARC	1.63	0.75	12.2	0.79	9.0
BARC	1.82	0.91	7.4	0.80	7.7
Rice straw	0.81	0.60	5.8	0.76	10.2
½ BARC + Rice straw	1.33	0.72	3.1	0.72	10.5

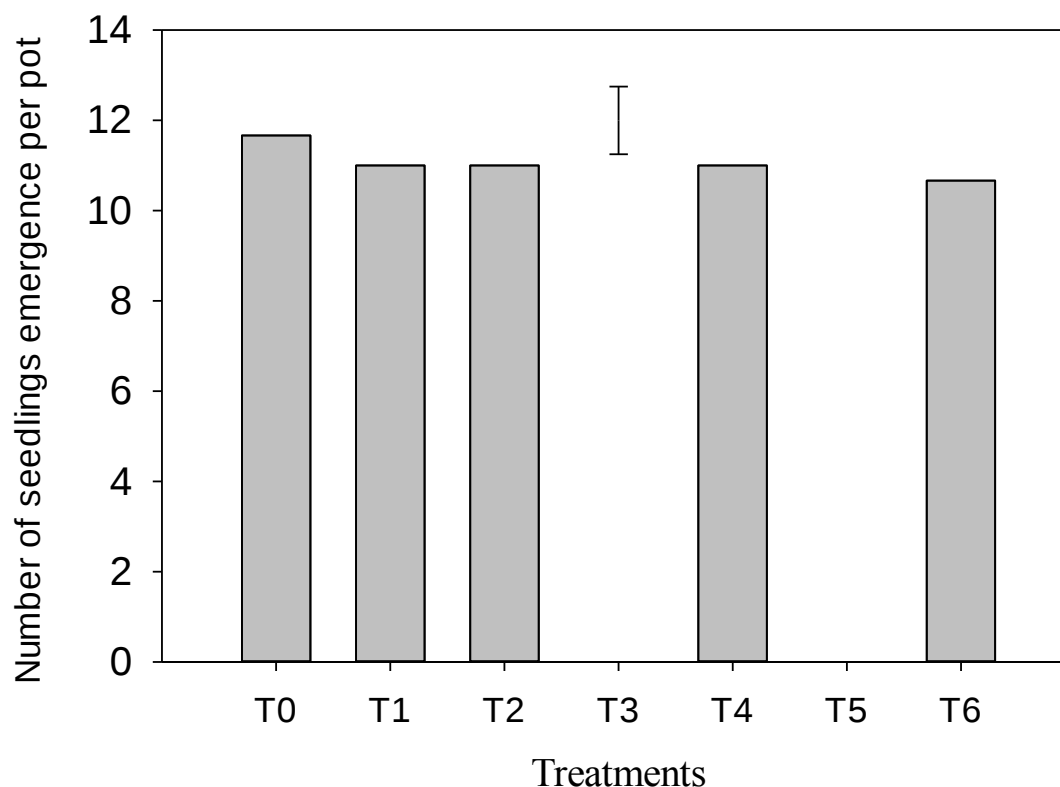


Figure.3. Number of seedlings emergence in several treatments. Vertical bar indicates LSD ($P \geq 0.05$) for treatment interaction. T_0 = Control, T_1 = Half of BARC recommended fertilizer, T_2 = BARC recommended fertilizer, T_3 = compound biochar only, T_4 = rice straw biochar only, T_5 = half of BARC recommended fertilizer plus compound biochar and T_6 = half of BARC recommended fertilizer plus rice straw biochar.

3.5 Biochar effect on wheat plant growth response

The number of seedlings emerged did not significantly differ among several treatments at 6 days after sowing (DAS). However, seedlings did not come out compound biochar and half BARC plus compound biochar treatments (Fig. 3).

Increase in plant height with respect to Days after Sowing (DAS) is shown in Fig. 4(a-d). Initially, plant height of rice straw biochar and $\frac{1}{2}$ BARC plus rice straw biochar was lower compared to control, $\frac{1}{2}$ BARC and BARC treatment. However, this difference became closer with DAS. The plant height at 21 DAS for control, $\frac{1}{2}$ BARC, BARC, rice husk biochar and $\frac{1}{2}$ BARC plus rice husk biochar were 29.63, 30.13, 31.03, 27.27 and 28.12 cm respectively. Similarly, the plant height at 43 DAS for control, $\frac{1}{2}$ BARC, BARC, rice husk biochar and $\frac{1}{2}$ BARC plus rice husk biochar were 38.10, 39.67, 42.61, 40.72 and 42.47 cm respectively. Likewise, the plant height at 60 DAS for control, $\frac{1}{2}$ BARC, BARC, rice husk biochar and $\frac{1}{2}$ BARC plus rice husk biochar were 51.53, 53.40, 55.90, 53.15 and 54.67 cm respectively.

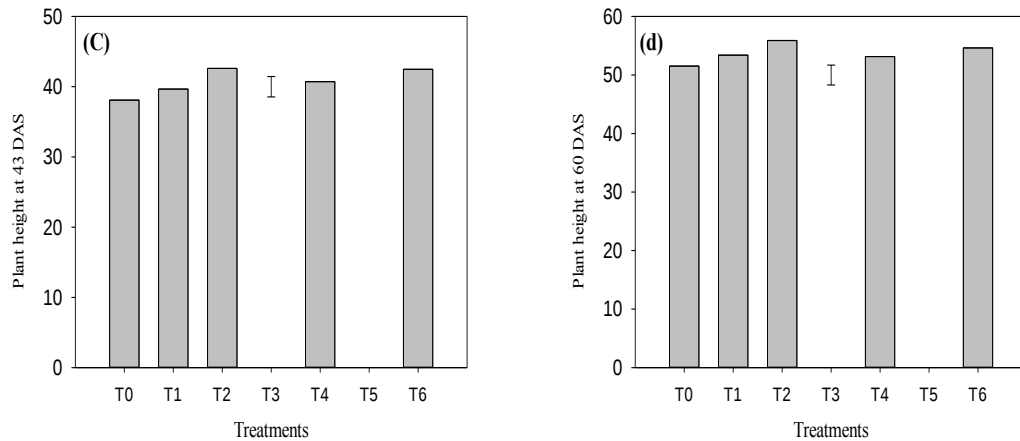


Figure 4(a-d): Plant height at 8 DAS in several treatments. Vertical bar indicates LSD ($P \geq 0.05$) for treatment interaction. T_0 = Control, T_1 = Half of BARC recommended fertilizer, T_2 = BARC recommended fertilizer, T_3 = compound biochar only, T_4 = rice straw biochar only, T_5 = half of BARC recommended fertilizer plus compound biochar and T_6 = half of BARC recommended fertilizer plus rice straw biochar.

The wheat plant height at harvest for several treatments was shown in Fig. 5. The plant height at harvest for control, $\frac{1}{2}$ BARC, BARC, rice husk biochar and $\frac{1}{2}$ BARC plus rice husk biochar were 60.40, 62.50, 64.88, 62.58 and 63.23 cm respectively. Statistical result showed that plant height at 60 DAS and harvest did not differ significantly between BARC and $\frac{1}{2}$ BARC plus rice straw biochar treatments (Table 10). This indicates that biochar can be utilized with the reduction rate of inorganic chemical fertilizer. It will help to minimize chemical fertilizer application in Bangladesh agriculture which will improve soil fertility and wheat productivity.

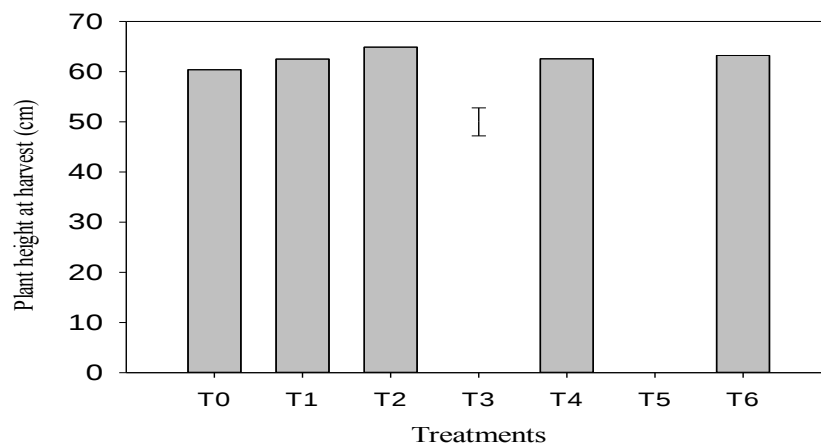


Figure 5. Wheat plant height at harvest for several treatments. Vertical bar indicates LSD ($P \geq 0.05$) for treatment interaction. T_0 = Control, T_1 = Half of BARC recommended fertilizer, T_2 = BARC recommended fertilizer, T_3 = compound biochar only, T_4 = rice straw biochar only, T_5 = half of BARC recommended fertilizer plus compound biochar and T_6 = half of BARC recommended fertilizer plus rice straw biochar.

Interestingly, the leaf area per plant was significantly ($P \geq 0.05$) highest in half BARC plus rice straw biochar treatment as compared to other treatments (Fig. 6). The lowest leaf area was found in the control treatment where nothing was added within soil. Half BARC, BARC and rice straw treatment did not differ significantly ($P \geq 0.05$) irrespective to leaf area. However, these treatments tended to be higher than control treatment.

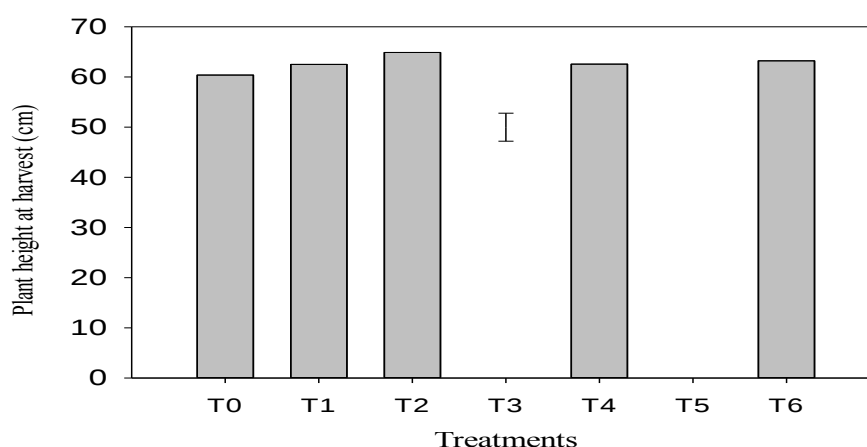


Figure 6. Wheat plant height at harvest for several treatments. Vertical bar indicates LSD ($P \geq 0.05$) for treatment interaction. T_0 = Control, T_1 = Half of BARC recommended fertilizer, T_2 = BARC recommended fertilizer, T_3 = compound biochar only, T_4 = rice straw biochar only, T_5 = half of BARC recommended fertilizer plus compound biochar and T_6 = half of BARC recommended fertilizer plus rice straw biochar.

The shoot dry weight at 35 DAS for $\frac{1}{2}$ BARC and BARC treatment was highest followed by the rice straw biochar treatments (Fig. 6). This could be due to the reason that rice straw biochar release slow nutrients that resulted less nutrient uptake by the wheat plant. However, all treatments had significantly ($P \geq 0.05$) higher shoot dry weight at 35 DAS than the control i.e nothing added treatment (Table 10).

Table 6. Changes in soil macro nutrient status due to biochar amendment in incubation experiment

Days of sampling	N in percent		P in ppm		K in me/100g		Ca in me/100g		Mg in me/100g		S in ppm	
	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound
0 days	0.08	0.08	29.80	29.80	0.31	0.31	15.53	15.53	2.43	2.43	36.1	36.1
62 days	0.09	0.10	23.17	335.10	1.10	1.10	15.72	12.97	5.01	5.93	54.9	780.1
159 days	0.10	0.12	7.90	198.90	1.11	1.11	15.89	13.73	8.13	8.76	94.3	907.3

Rice straw biochar had remarkable effect on root proliferation. The root proliferation after harvest was similar between $\frac{1}{2}$ BARC and rice straw treatment. Similarly, root proliferation was same between BARC and $\frac{1}{2}$ BARC plus rice straw treatment. Rice straw biochar treatments noticeably facilitate root proliferation in this experiment (Fig. 9). This may help to more nutrient uptake by wheat plant in the rice straw added treatments.

3.6 Effect of rice straw biochar on yield of wheat

The spike length was highest in BARC treatment followed by $\frac{1}{2}$ BARC in combination with rice straw biochar, rice straw biochar only, $\frac{1}{2}$ BARC only and nothing added treatments (Fig. 10). The spike length per pot for control, $\frac{1}{2}$ BARC, BARC, rice husk biochar and $\frac{1}{2}$ BARC plus rice husk biochar were 8.93, 9.92, 10.61, 9.48 and 10.1 cm respectively.

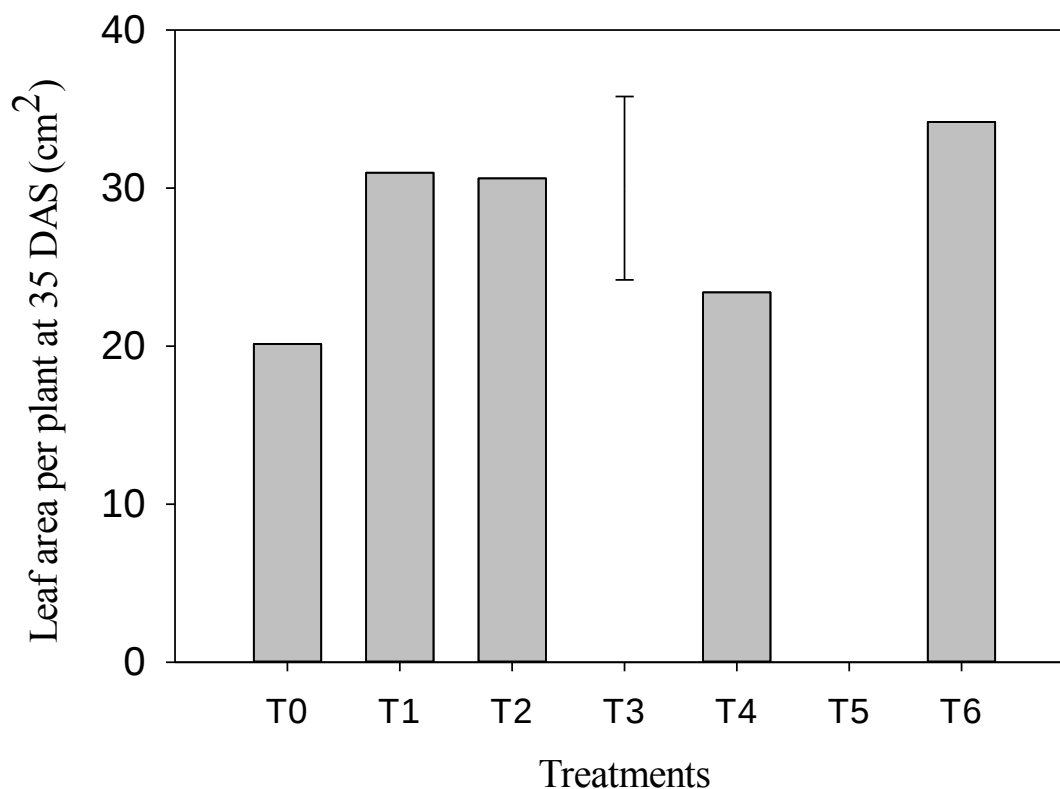


Figure 7. Leaf area at 35 DAS in several treatments. Vertical bar indicates LSD ($P \geq 0.05$) for treatment interaction. T_0 = Control, T_1 = Half of BARC recommended fertilizer, T_2 = BARC recommended fertilizer, T_3 = compound biochar only, T_4 = rice straw biochar only, T_5 = half of BARC recommended fertilizer plus compound biochar and T_6 = half of BARC recommended fertilizer plus rice straw biochar.

The thousand grain weight was similar between BARC and combined $\frac{1}{2}$ BARC with rice straw biochar amended treatment (Fig. 11). The thousand grain weight per pot for control, $\frac{1}{2}$ BARC, BARC, rice husk biochar and $\frac{1}{2}$ BARC plus rice husk biochar were 44.53, 46.33, 47.93, 46.13 and 47.53 g/pot respectively.

The grain yield was similar between BARC and $\frac{1}{2}$ BARC plus rice straw biochar treatment (Fig. 12). However, grain yield significantly ($P \geq 0.05$) increased all inorganic fertilizer and rice straw biochar amended treatments as compared to control i.e nothing added treatment.

Like as grain yield the straw yield was similar between BARC and $\frac{1}{2}$ BARC plus rice straw biochar treatment (Fig. 13). Straw yield significantly ($P \geq 0.05$) increased among all

treatments from the nothing added treatment (Table 11). The straw yield for control, $\frac{1}{2}$ BARC, BARC, rice husk biochar and $\frac{1}{2}$ BARC plus rice husk biochar were 4.79, 5.02, 5.92, 5.20 and 5.86 g/pot respectively.

Table 7. Changes in soil micro nutrient status due to biochar amendment in incubation experiment.

Days of sampling	Zn in ppm		B in ppm		Fe in $\mu\text{g/g}$		Cu in $\mu\text{g/g}$		Mn in $\mu\text{g/g}$		S in $\mu\text{g/g}$	
	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound	Rice straw	Compound
0 days	0.51	0.51	0.62	0.62	12.9	21.1	0.79	0.75	8.8	72.7	34.9	780.1
62 days	0.31	0.74	0.40	4.94	7.4	22.3	0.76	0.78	10.2	75.7	35.9	785
159 days	0.40	1.09	0.81	3.03	6.2	24	0.72	0.79	10.5	79.4	40.2	790

Discussion

4.1 Incubation effect Both rice straw and compound biochar has potentiality to increase soil organic matter and reduce soil pH due to incubation (Table 5). Biochar amendment decreased soil pH by 0.3 units for rice straw biochar and 0.9 for compound biochar. A similar type of incubation study found that biochar incorporation declined soil pH with time (Liu and Zhang, 2012). They speculated that acidic materials produced by the oxidation of biochar and organic matters may have caused the pH decrease. Because, the formation of the acidic functional groups can neutralize alkalinity and eventually decrease soil pH. Similarly, the dilution of the cations in the biochar may decrease soil pH at the initial phase when biochar is mixed with soils. Findings also indicated that soil organic matter status dramatically increased in biochar amended soil. This increasing trend also rapidly rises with incubation time (Table 5). Increases in soil organic matter by biochar amendment were also observed by a number of researchers (McHenry, 2011). Likewise, Ming *et. al.* (2015) found that the biochar-amended soils had 37.7, 7.3 and 227.6% more soil organic carbon (SOC) than the control soil. It may be due to the reason that concerning possible priming effect whereby accelerated decomposition of soil organic matter occurs upon biochar addition to soil (Verheijen *et. al.*, 2009). Other short term (59 d) incubation study found that biochar amendment reduced soil pH and increased soil organic matter (Wu *et. al.*, 2014). They speculated that soil pH reduction in biochar amended soil due to loss of acidity in pyrolysis process. Lower pH is beneficial for the dissolution and activation of some difficult soluble elements thus increasing the ionic concentration of soil solution (Yuan and Xu'2011). However, many reports have showed soil pH increases due to biochar application (Yuan *et. al.*, 2011). Most of these studies have been performed on acidic soils with low pH in comparison to the biochar pH. This study was conducted in alkaline soil with an initial soil pH was 8.3 as well as rice straw biochar pH was 8.02 and compound biochar pH was 8.87 (Table 5 and Table 2). Liu and Zhang (2012) reported that alkaline biochar did not increase the pH of five types of alkaline soils, but instead produced a decreasing pH trend. The alkaline soil used for the study had also pH of 8.3, which could have prevented any biochar liming effect. High pH soil could result in lowering pH in the high pH biochar amended soils. Because, biochar is not at all inert and can be oxidized in soil, especially at its surface (Cheng

et. al., 2006). This clearly indicated that biochar amended incubated soil has the potential to increase soil organic matter and reduce soil pH.

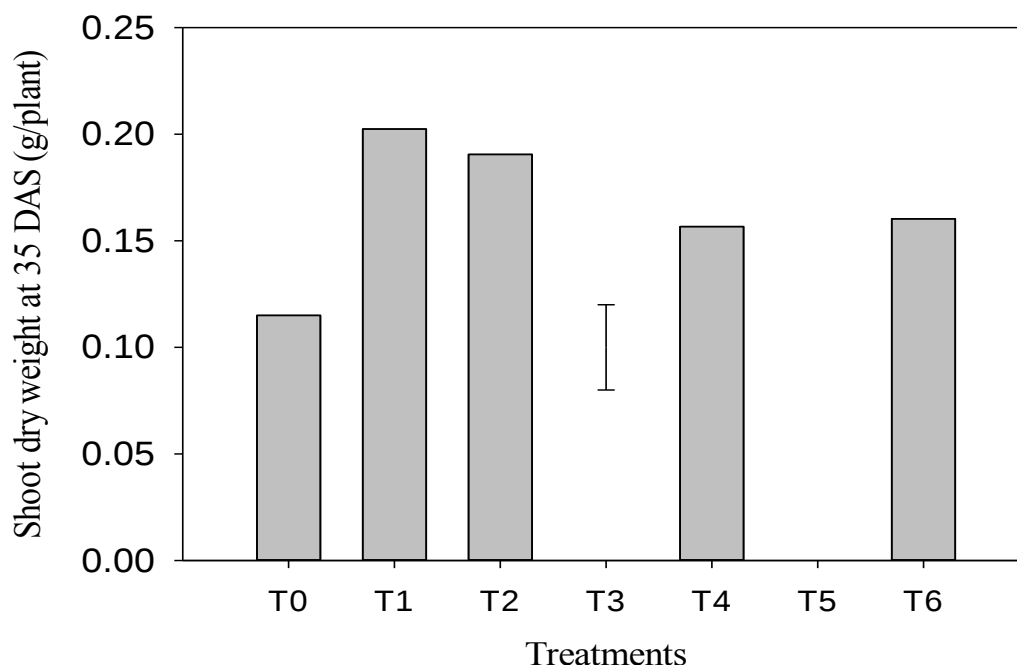


Figure 8. Shoot dry weight at 35 DAS in several treatments. Vertical bar indicates LSD ($P > 0.05$) for treatment interaction. T_0 = Control, T_1 = Half of BARC recommended fertilizer, T_2 = BARC recommended fertilizer, T_3 = compound biochar only, T_4 = rice straw biochar only, T_5 = half of BARC recommended fertilizer plus compound biochar and T_6 = half of BARC recommended fertilizer plus rice straw biochar.

4.2 Effect of compound biochar on wheat germination

Compound biochar has negative effect on wheat germination. The coleoptile was not able to come out in the compound biochar added treatment (Fig. 3). It was tried two times to survive wheat seedlings through transplantation. But, it was not succeeded. This could be due to the reason that the rate of compound biochar application was high. It is necessary to judge the compound biochar effect on germination of wheat plant. Because, applied compound biochar amendment rate was high (66.67 g/kg soil) in this experiment. Several study also viewed similar opinion. Rondon *et. al.*, (2007) found that instances of decreasing yield due to a high biochar application rate were reported when the equivalent of 165 t of compound biochar/ha was added to a poor soil in a pot experiment. It was hypothesized that germination, growth and yield of wheat plant will be highest in compound biochar treatment among other treatments. However, it could not be happen due to application of high rate compound biochar. Further, experiment will be conducted in the following year with the reduction of compound biochar application rate for wheat production.

Table 8. Bulk soil chemical properties and macro nutrient contents

Treatments	Soil pH	Organic matter (%)	TN (%)	P ($\mu\text{g/g}$)	K (cmol^+/kg)	Ca (cmol^+/kg)	Mg (cmol^+/kg)	S ($\mu\text{g/g}$)
Control	8.7	1.34	0.08	13.7	0.27	14.37	2.67	28.2
$\frac{1}{2}$ BARC	8.7	1.39	0.09	14.2	0.26	14.13	2.66	31.6
BARC	8.6	1.31	0.08	13.2	0.26	14.05	2.74	27.9
Rice straw	8.3	1.57	0.09	13.1	0.96	13.34	2.67	40.2
$\frac{1}{2}$ BARC + Rice straw	8.4	1.69	0.10	13.8	0.95	12.79	2.69	35.3

4.3 Biochar amendments improves nutrient availability in soil

Biochar amendments are potential to improve nutrient availability in soil. Application of biochar increase N and K availability in soil (Table 6). Other study also found similar result. Tammeg et. al., (2014) evaluated 0, 5, 10, 20 and 30 t/ ha of biochar without inorganic fertilizer and found that biochar improved N and K content in soil. Similarly, Mg content increased with incubation in both rice straw and compound biochar (Table 6). Nigusse et. al., (2012) evaluated 0, 5 and 10 t/ha of biochar in a field experiment. They found that Mg content increased 6.91 to 7.12 ppm due to this biochar amendment.

Table 9. Bulk soil micro nutrient contents

Treatments	B ($\mu\text{g/g}$)	Zn ($\mu\text{g/g}$)	Fe ($\mu\text{g/g}$)	Cu ($\mu\text{g/g}$)	Mn ($\mu\text{g/g}$)
Control	1.16	0.64	11.9	0.78	10.0
$\frac{1}{2}$ BARC	1.63	0.75	12.2	0.79	9.0
BARC	1.82	0.91	7.4	0.80	7.7
Rice straw	0.81	0.60	5.8	0.76	10.2
$\frac{1}{2}$ BARC + Rice straw	1.33	0.72	3.1	0.72	10.5

A study showed that K, Mg and Ca content was 0.09, 0.21 and 0.31 cmol^+/kg soil in a fine sandy loam soil. However, K, Mg and Ca content reached to 0.23, 0.34 and 0.31 cmol^+/kg soil due to rice straw biochar amendment. Similarly, Major et. al., (2010) attributed the greater crop yield and nutrient uptake in their 4 year field trial to 77-320% more Ca and Mg in soil where biochar was applied. The increased N content in biochar amended soil may be due to the biochar efficiency to adsorbs ammonia (NH_3) and acts as a binder for ammonia in soil, therefore, having the potential to decrease ammonia volatilization losses from soil (Oya and Iu, 2002). Regardless of that bulk soil N,P and K status increased with combining biochar with $\frac{1}{2}$ BARC recommended treatment (Table 8). Likewise, Gandahi et. al., (2015) residual N, P and K status in soil increased in the integrating rice straw biochar with N, P and K fertilizers on a low fertility soil. They speculated that although residual N, P and K status in soil increased but increase in soil pH was not good sign for calcareous soils and it was may be due to alkali nature of rice husk biochar.

Table 10. Significance levels from the analysis of variance for the main effects on growth response of wheat seedlings.

Source of variation	Seedling emergence	Plant height at 8 DAS	Plant height at 21 DAS	Plant height at 43 DAS	Plant height at 60 DAS	Plant height at harvest	Leaf area at 35 DAS	Shoot dry weight at 35 DAS
Treatments	n.s.	***	*	n.s.	n.s.	n.s.	n.s.	*

Where n.s., *, ** and *** represent probability of > 0.05 , ≤ 0.05 , ≤ 0.01 and ≤ 0.001 . Values were means of three replicates.

Table 11. Significance levels from the analysis of variance for the main effects on yield response of wheat plant.

Source of variation	Spike length	Thousand grain weight	Grain yield	Straw yield
Treatments	***	*	***	**

4.4 Effect of rice straw biochar on wheat production

Rice straw biochar has positive response on growth and yield of wheat. Result showed that several growth parameters like plant height, leaf area and shoot dry weight of wheat plant tended to be greater in rice straw biochar only compared to control (Fig. 2 to Figure 8). Similarly, several yield parameters like spike length, thousand grain weight, grain yield and straw yield were higher in rice straw biochar only compared to control (Fig. 9 to Fig. 12). These both growth and yield parameters were also more in combined half BARC plus rice straw biochar than only rice straw biochar treatment. These indicate that some inorganic fertilizer can speed up growth and yield performance of the BARI Gom 28 when added with rice straw biochar. Gebremedhin *et al.*, (2015) found similar results. They have conducted a pot experiment to evaluate effect of biochar on wheat productivity and soil properties. They also have used combination of biochar and chemical fertilizer.

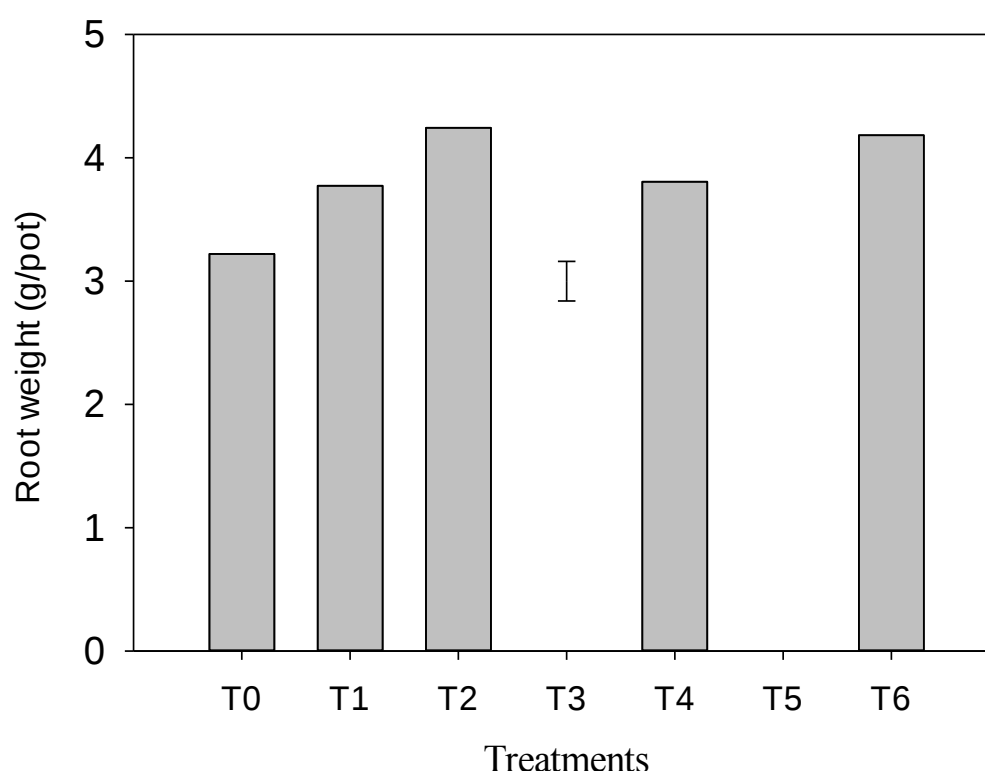


Figure 9. Root dry weight after harvest in several treatments. Vertical bar indicates LSD ($P > 0.05$) for treatment interaction. T_0 = Control, T_1 = Half of BARC recommended fertilizer, T_2 = BARC recommended fertilizer, T_3 = compound biochar only, T_4 = rice straw biochar only, T_5 = half of BARC recommended fertilizer plus compound biochar and T_6 = half of BARC recommended fertilizer plus rice straw biochar.

They found that plant height at maturity for chemical fertilizer was 64.53 cm and increased to 66.8 cm due to combined biochar and chemical fertilizer application. This study also showed that plant height at maturity for chemical fertilizer (half of BARC recommendation) was 62.50 cm and it reached to 63.23 cm due to addition of rice straw biochar with half of BARC recommended chemical fertilizer for wheat production (Fig. 5). Other growth and yield parameters also increase in combined chemical fertilizer and rice straw biochar added treatment. Similarly, in this experiment other growth and yield parameters also increased in combined chemical fertilizer and rice straw biochar added treatment (Fig. 6 to Fig. 12). It was speculated that biochar retains nutrients and water to improve wheat productivity. Likewise, Lehman *et. al.*, (2003) speculated that biochar serves as a direct source of nutrients for plant uptake that results increased wheat production. Similarly, Vaccari *et. al.*, (2011) found that biochar application increased wheat yield by 30%.

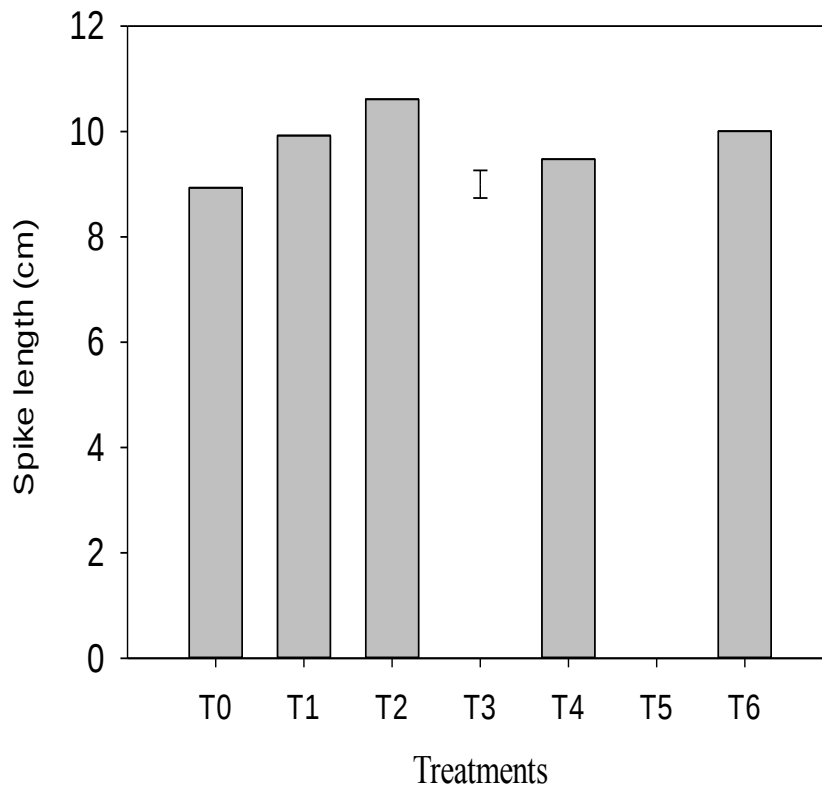


Figure 10. Spike length of wheat plant in several treatments. Vertical bar represents LSD ($P > 0.05$) for treatment interaction. T_0 = Control, T_1 = Half of BARC recommended fertilizer, T_2 = BARC recommended fertilizer, T_3 = compound biochar only, T_4 = rice straw biochar only, T_5 = half of BARC recommended fertilizer plus compound biochar and T_6 = half of BARC recommended fertilizer plus rice straw biochar.

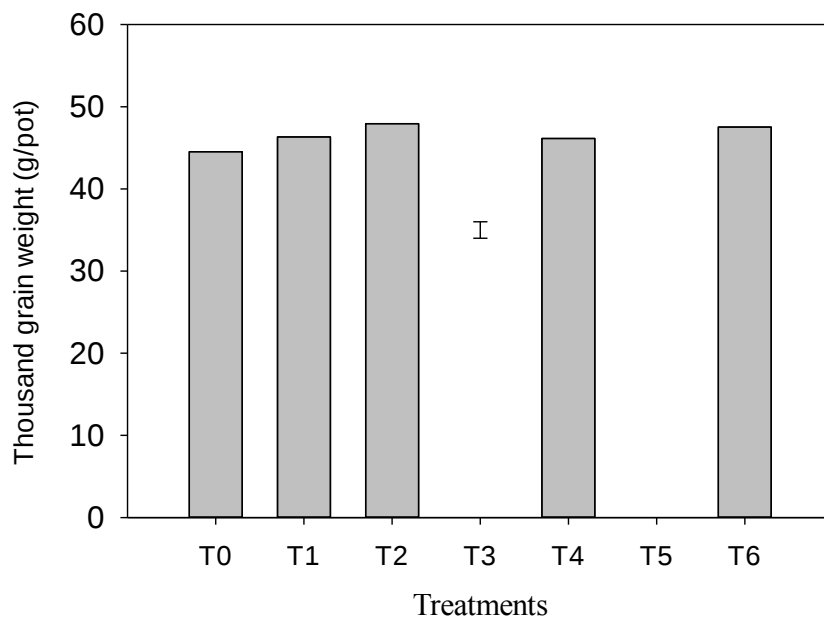


Figure 11. Thousand grain weight in several treatments. Vertical bar indicates LSD ($P > 0.05$) for treatment interaction. T_0 = Control, T_1 = Half of BARC recommended fertilizer, T_2 = BARC recommended fertilizer, T_3 = compound biochar only, T_4 = rice straw biochar only, T_5 = half of BARC recommended fertilizer plus compound biochar and T_6 = half of BARC recommended fertilizer plus rice straw biochar.

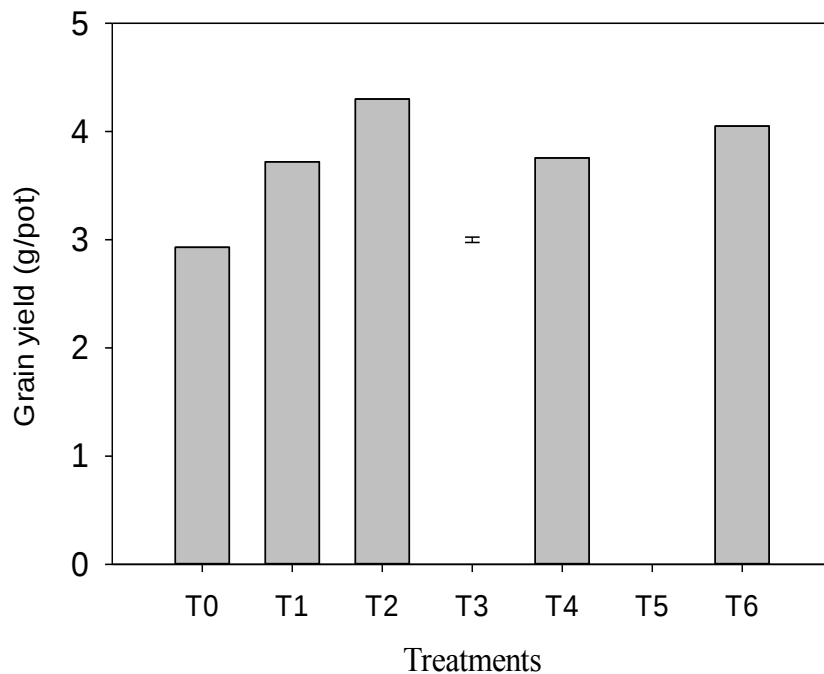


Figure 12. Wheat yield for several treatments. Vertical bar indicates LSD ($P > 0.05$) for treatment interaction. T_0 = Control, T_1 = Half of BARC recommended fertilizer, T_2 = BARC recommended fertilizer, T_3 = compound biochar only, T_4 = rice straw biochar only, T_5 = half of BARC recommended fertilizer plus compound biochar and T_6 = half of BARC recommended fertilizer plus rice straw biochar.

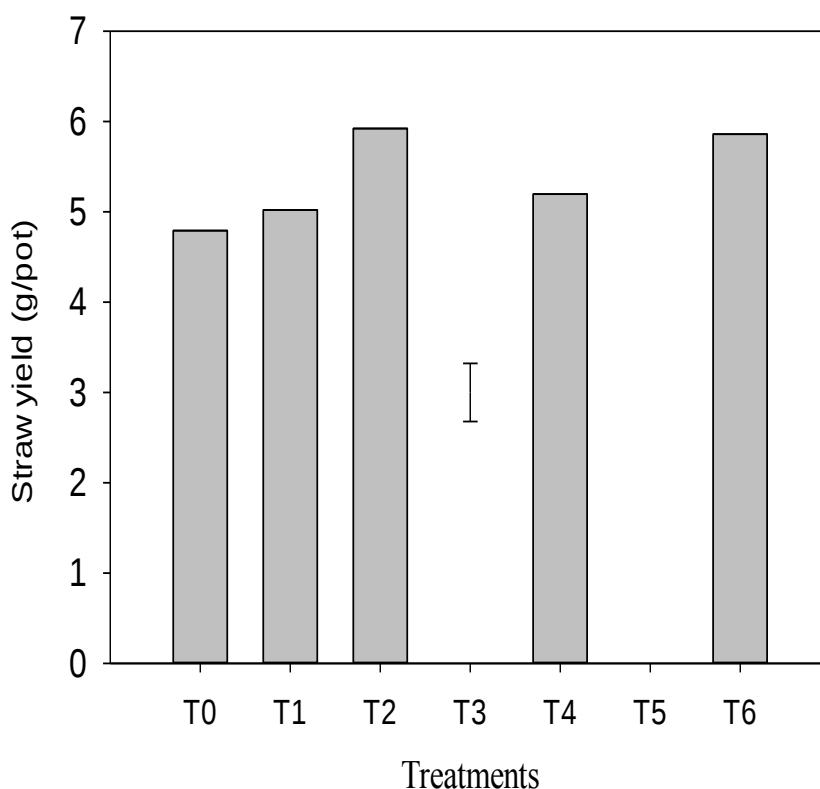


Figure 13. Straw yield for several treatments. Vertical bar indicates LSD ($P > 0.05$) for treatment interaction. T_0 = Control, T_1 = Half of BARC recommended fertilizer, T_2 = BARC recommended fertilizer, T_3 = compound biochar only, T_4 = rice straw biochar only, T_5 = half of BARC recommended fertilizer plus compound biochar and T_6 = half of BARC recommended fertilizer plus rice straw biochar.

Conclusion

This study demonstrated that both rice straw and compound biochar amendment increases soil fertility within incubated soils after 159 days of incubation. This study revealed that both rice straw and compound biochar amendment increases soil organic matter status within incubated soils after 159 days of incubation. In contrast, soil pH declined in both biochar amended incubated soil. The combination of rice straw biochar and $\frac{1}{2}$ BARC fertilizer dose gave better effect than single application rice straw biochar and gave second highest yield of wheat. However, highest yield was observed in BARC recommended fertilizer applied treatment. It indicates that biochar could be used as nutrients to achieve comparable yields to that obtained with inorganic fertilizers. This study recommended that utilization of rice straw derived biochar is authoritative in order to increase soil fertility status and wheat productivity in Bangladesh. Further study will be conducted with the reduction of compound biochar amendment to soil for wheat production.

Acknowledgement

The author is thankful to University Grants Commission, Bangladesh for financial support to conduct this research work. The author also thanks Professor Lianqing Li, Institute of Resource, Ecosystem and Environment of Agriculture, Center of Biochar & Green Agriculture in Nanjing Agricultural University for providing compound and rice straw biochar. The author is grateful to anonymous reviewer for valuable suggestions.

References

- Ahmed, F., MS. Islam, MT Iqbal. 2017. Biochar amendment improves soil fertility and productivity of mulberry plant. *Eurasian Journal of Soil Science*, 6(1), 37-43.
- Bhuiyan SS, MAR Joadder, AS Bhuiyan. 2008. Occurrence of fishes and non-fin fishes of the river Padma near Rajshahi, Bangladesh. *University Journal of Zoology*, Rajshahi University 27, 99-100.
- Biswas, A., M. Alamgir, SMS Haque, KT Osman. 2012. Study on soils under shifting cultivation and other land use categories in Chittagong Hill Tracts, Bangladesh. *Journal of Forest Research*, 12(2), 261-265.
- Cheng, CH., J. Lehmann, JE. Thies, SD Burton, MH Engelhard. 2006. Oxidation of black carbon by biotic and abiotic processes. *Organic Geochemistry*, 37, 1477–1488.
- Dias, BO, Silva, CA, Higashikawa, FS, Roig, A and Sanchez-Monedero, MA, 2010: Use of biochar as bulking agent for the composting of poultry manure; effect on organic matter degradation and humification. *Bioresource Technology* 101, 1239–1246.
- Gandahi, AW., SF Baloch, MS Sarki, , R. Gandahi, MS Lashari. 2015. Impact of rice husk biochar and macronutrient fertilizer on fodder maize and soil properties. *International Journal of Biosciences* 7(4), 12-21.
- Gebremedhin, GH, B. Haileselassie, D. Berhe, T. Belay. 2015. Effect of Biochar on Yield and Yield Components of Wheat and Post-harvest Soil Properties in Tigray, *Ethiopian Journal of Fertilizer and Pesticide* 6, 158 (doi:10.4172/2471-2728.1000158).
- Glaser, B., J. Lehmann, and W. Zech. 2002. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal—a review. *Biology and Fertility of Soils* 35, 219–230.
- Hammer, E. C., Z. Balogh-Brunstad, I. Jakobsen, P. A. Olsson, S. L. S. Stipp, M. C. Rillig. 2014. A mycorrhizal fungus grows on biochar and captures phosphorus from its surfaces. *Soil Biology and Biochemistry* 77, 252–260. (10.1016/j.soilbio.2014.06.012)
- Huq, SMI. and MD Alam. 2005: A Handbook on analyses of soil, plant and water. BACER-DU, University of Dhaka, Bangladesh. PP. 13-40.
- Kamara, A., HS. Kamara, MS Kamara. 2015. Effect of Rice Straw Biochar on Soil Quality and the Early Growth and Biomass Yield of Two Rice Varieties *Agricultural Sciences*, 6, 798-806
- Lehmann, J. 2007. Bio-energy in the black. *Frontiers in Ecology and Environment* 5, 38–387.
- Lehmann, J and M. Rondon. 2006. Bio Char soil management on highly weathered soils in the humid tropics. In: N. Uphoff et al. (eds.), *Biological approaches to sustainable soil systems*. Florida: CRC Press, Taylor and Francis Group. p. 517–530.

- Lehman, J and S. Joseph. 2009. Biochar systems. In: Lehman CJ, Joseph S. (Eds.), Biochar for environmental management: science and technology. Earthscan. London, pp. 20-222.
- Lehmann, J., JP. da Silva Jr, C. Steiner, T. Nehls, W. Zech, and B. Glaser. 2003 Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments *Plant Soil* 249, 343-357.
- Liu, XH and XC Zhang,. 2012 Effect of biochar on pH of alkaline soils in the loess plateau: results from incubation experiments. *International Journal of Agriculture and Biology*, 14, 745–750
- Major, J, M. Rondon, D. Molina, S. Riha, and J. Lehmann. 2010. Maize yield and nutrition during 4 years after biochar application to a Colombian savanna oxisol. *Plant Soil* 333, 117-128.
- McHenry, MP : 2011 Soil organic carbon, biochar, and applicable research results for increasing farm productivity under Australian agricultural conditions. *Communications in Soil Science and Plant Analysis* 42(10), 1187-1199.
- Ming, LI., LIU Ming , LI Zhong-pei, JIANG Chun-yu, WU Meng. 2015. Soil N transformation and microbial community structure as affected by adding biochar to a paddy soil of subtropical China *Journal of Integrative Agriculture*, (DOI : 10.1016/S2095-3119(15)61136-4)
- Nigussie, A., E. Kissi, M. Misganaw, G. Ambaw. 2012. Effect of Biochar Application on Soil Properties and Nutrient Uptake of Lettuces (*Lactuca sativa*) Grown in Chromium Polluted Soils *American-Eurasian Journal of Agriculture and Environment Science* 12(3), 369-376.
- O'Neill, B, J. Grossman, MT. Tsai, JE. Gomes, JJ. Lehmann, Peterson, E. Neves, and JE. Thies. 2009. Bacterial community composition in Brazilian Anthrosols and adjacent soils characterized using culturing and molecular identification. *Microbial Ecology* 58, 23–35.
- Oya A, WG. Iu. 2002. Deodorization performance of charcoal particles loaded with orthophosphoric acid against ammonia and trimethylamine. *Journal of soil use and management* 40(9), 1391-1399.
- Petersen, L. 1996. Soil analytical methods soil testing Management and development, soil resources development Institute, Dhaka, Bangladesh. pp. 1-28.
- Piper, CS :1950 Soil and plant analysis. Adelaide University. Hassel Press, Australia. 368p.
- Podder, M, M. Akter, ASM Saifullah, S. Roy, 2012. Impacts of plough pan on physical and chemical properties of soil. *Journal of Environmental Science and Natural Resource* 5(1), 289-294.
- Raj Paroda, S. Dasgupta, Mal Bhag, SS Singh, ML Jat and Singh Gyanendra. 2012. Proceedings of the Regional Consultation on Improving Wheat Productivity in Asia , Bangkok, Thailand, 26-27 April, 2012.
- Rondon, MA, J, Lehmann, J, Ramirez, M. Hurtado. 2007. Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with bio-char additions. *Biology and Fertility of Soils* 43, 699.
- Skjemstad, JO., DC. Reicosky, AR Wills, and JA. McGowan. 2002. Charcoal carbon in U.S. agricultural soils. *Soil Science Society of America Journal* 66, 1249–1255.

Soltanpour, PN, AP. Schwab. 1997. A new soil test for simultaneous extraction of macro- and micronutrients in alkaline soils. *Communications in Soil Science and Plant Analysis*. 8, 195-207.

Sohi, S, E. Krul, E. Lopez-Capel, R. Bol. 2010. A review of biochar and its use and function in soil. *Advance in Agronomy* 105, 47-82.

Solaiman, ZM, P. Blackwell, LK Abbott, P. Storer. 2010. Direct and residual effect of Use of biochar as bulking agent for the composting of poultry manure: effect of organic matter degradation and humification. *Bioresource Technology* 101, 1239-1246.

Subbiah, B and GL. Asija. 1956 A rapid procedure for estimation of available nitrogen in soils. *Current Science*, 26-29.

Tammeorg, P., A. Simojoki, P. Mäkelä, FL. Stoddard, L. Alakukku, & J. Helenius. 2014. 'Short-term effects of biochar on soil properties and wheat yield formation with meat bone meal and inorganic fertiliser on a boreal loamy sand', *Agriculture, ecosystems & environment*, 191, 108-16.

Vaccari, FP., S. Baronti, E. Lugato, L. Genesio, S. Castaldi, F. Fornasier, and F. Miglietta. 2011. Biochar as a strategy to sequester carbon and increase yield in durum wheat. *European Journal of Agronomy* 34, 231-238.

Verheijen, FGA, S. Jeffery, AC Bastos, M. van der Velde, and I. Diafas. 2009. Biochar Application to Soils - A Critical Scientific Review of Effects on Soil Properties, Processes and Functions. EUR 24099 EN, Office for the Official Publications of the European Communities, Luxembourg, 149pp.

Warnock, DD, J. Lehmann, TW Kuyper, and MC. Rillig. 2007. Mycorrhizal responses to biochar in soil-concepts and mechanisms *Plant Soil* 300, 9–20.

Walkley, A and IA. Black. 1934. An Examination Degtijareff method for determining soil organic matter and a proposed modification of chromic acid titration method. *Soil Science* 37, 29-38.

Wu, Y., Y. Gu, and HB Shao. 2014. Furfural and its biochar improve the general properties of a saline soil *Solid Earth* 5, 665–671

Yuan, JH and RK. Xu. 2011. The amelioration effects of low temperature biochar generated from nine crop residues on an acidic Ultisol, *Soil Use Management*, 27. 110–115.

Yuan JH, RK. Xu, W Qian, RH Wang. 2011. Comparison of the ameliorating effects on an acidic ultisol between four crop straws and their biochars. *Journal of Soils & Sediments*, 11(5), 741–750.



Sustainable Development in Education of Horticulture



Nidal Shaban*, **Sergei Bistrichanov***, Eman Kadum**,
Miroslav Tityanov*

*University of Forestry, 1756 Sofia, 10 "Kl. Ohridski" str.

**Agricultural academy, 1517, Sofia, № 30 "Suchodolska" str

Corresponding Author: Nidal Shaban, e-mail: nidalshaban@abv.bg

Abstract

Sustainable development in education of horticulture imposes involvement of new system in education of agricultural experts (in particular vegetable growers); include – ethical view off point to the reality of production, synthesis of traditional practices (crop rotation, mixed crops, etc.), the love to the land inherited from ancestors and modern scientific achievements from this perspective which will have a positive environmental effect over the agrarian ecosystems and the environment in general. From this perspective lectures and practices should be based on the principles of integration of different systems and methods of production; this will include sustainable management of fertilizing and irrigation; energy use associated with production; integrated control of pests with sustainable application in the farms. These principles should be presented in a special section entitled "Sustainable Growing of Vegetables" which will form the basic knowledge related to the topic; they should be incorporated in a suitable place in the respective sections for individual crops where developed of details with active participation of trained people.

In order to overcome the specified problems and ensure sustainable development of the sector its necessary to provide well-trained people who know not only the traditional technologies used at present but also the principles of sustainable agriculture as well, especially related with keeping natural resources to next generations.

Key words: sustainable development, horticulture, students, training

List of abbreviations used in the manuscript:

SED-Sustainable education development, **UN**-United Nation, **ESSD**- Environmentally Sound and Sustainable Development, **IFOAM** International Federation of Organic Agriculture Movements, **PDRA**- Program for Development of Rural Areas, **MAF**-Ministry of Agriculture and Food

Introduction

The principles of sustainable development are universal and can be studied and implemented with success in agriculture and in particular the training of personnel dealing with similar specific activity. According to the definition of the World Commission on Environment and Development viable, stable or Sustainable development is such development that satisfying the needs of today's society without threatening future generations

of scarcity of goods for their needs. The (requisitely) holistic and interdisciplinary approaches to introduce Education for Sustainable Development (ESD), the attention to achieving tangible results, the involvement of local communities and the bottom-up approaches, the importance of partnerships and networking, the capacity building, the innovation of the initiatives, the attention given to building a framework favorable to Sustainable Development (SD), tutoring (tutor as mediator) and VCEN (values/culture/ethics/norms). Such a development in the training of well-trained agricultural staff (in particular producers of vegetable production) means that should look for a synthesis of traditional practices (crop rotation, mixed cropping and etc.) and inherited from our ancestors love for the land with modern achievements. Research investigation in this direction, which would have a positive environmental effect on both nature and agroindustry. In this connection temptation of teaching material should be based on the principles of integration of different systems and production methods that include sustainable management of food and irrigation system, integrated pest control implemented in a sustainable farm. During the UN Conference related to environment and development in Rio de Janeiro in 1992 a definition was accepted in relation to the stable, i.e. sustainable development; this means development which meets the needs of modern society with no danger presented with regard to future generations and possible deficiency of produce covering the needs of these generations. A so-called “Agenda 21” was published with the topic of “Environmentally Sound and Sustainable Development” (ESSD). This included 40 chapters and 115 different programs for stable development for all activities. In the 14th of these paid special attention directed toward “sustainable agricultural production and rural development”; 12 different programs were included creation, popularization and training of people in relation to technologies which help the conservation and rehabilitation of land. (14)

Sustainable life depends of ethics of interdependence and the end of one-sided and short-term behavior. Both of them belong to systemic behavior and receive support from social responsibility of humans and their organizations, such as enterprises, countries, non-governmental organizations, or families. Methodologically, it can be supported also by De Bono’s methods of „lateral thinking“, „six thinking hats“ and CoRT (Cognitive Research Trust). (13,6,2,3).

Higher education institutions training people for the sphere of Bulgarian agriculture in the 1990s (in 1987 in the Agricultural University in Plovdiv an agro-environmental centre was opened; it became a member of IFOAM in 1993 and had as a basic task the preparation of people and support of biologically-friendly agriculture in the country) we had the start of introduction of environmental elements in the programs and independent disciplines related to study plans; a number of handbooks were published in relation to this (8;10; 11). The ecological training of agricultural producers is already a prerequisite for receiving subsidies in relation to measure 214 “Agro-Environmental Payments” associated with the PDRA (Program for Development of Rural Areas) (Article 20 of Ordinance No. 11/2009).

The analysis of Hadzhieva (2007) of the period 1997-2005 showed that Bulgarian agriculture was still far from being sustainable and we had to pay attention to pollution, use of manure, soil erosion, income and productivity in the field. This finding has not lost its importance and it was established also in the National Plan for Development of Biologically-

Friendly Agriculture During the Period 2007–2013 (MAF); there in the second section of the analysis on weaknesses we see “problems related to training, education and consultancy services regarding biologically-friendly agriculture”. This means its very important to pay more attention to the introduction of students studying in this field to the specifics of the sphere; to analyze the current status of the problem, examine more closely the international experience and specify goals for a more successful application of sustainable development.

This paper aimed to involve principle(SED) to produce well-trained people who know not only the traditional technologies used at present but also the principles of sustainable agriculture as well, especially related with keeping natural resources to next generations

1. Special Characteristics, Problems and Specifics of Vegetable Growing

Fresh and processed vegetables are important and permanent part of the food of modern humans; their consumption around the world is growing constantly. Vegetable growing is a part of the general agricultural practice but it is a specialized activity and has a number of special characteristics. The most important of these are the following:

- Use of cultivation facilities (basic and complex) for growing and production in general or for a specific period of their vegetation;

- Growing by preliminary development of seedlings;

The specifics of Bulgarian vegetable growers can be grouped as follows:

- small-scale and fragmented growing with low level of specialization;
- keeping the significance of family gardens, natural and semi-market farms;
- significant reduction in agricultural production volumes;
- low quality and yields for produced vegetables due to the failure to comply with agro-technical requirements on the part of agricultural producers;
- higher requirements to quality and hygiene presented by importers.

1.1. Specifics of the Field

he production of vegetables is associated with high costs and this means higher prices of final products; this brings difficulties associated with sales. There is also some negative influence presented by the direct subsidies per hectare of land which forces agricultural producers to start growing crops with lower costs per land unit.

- Loss of traditional foreign markets due to changed external trade situation and poor competitiveness of Bulgarian agricultural product on the international market;

- Real threat for Bulgarian producers to be replaced as basic suppliers of fresh produce to large supermarket chains;

- High prices of Bulgarian vegetables which makes canned products impossible to sell in the local market;

- Limited assortment for companies due to the lower purchasing power of the Bulgarian population and use of home made produce;

- In production of vegetables exist many problems such as a lack of effective organization of production activities (still have low technological level, production with high costs, high prices of seeds, mineral nutrition, plant protection chemical products, price of water for irrigation; absence of mechanical tools and use of human labour in relation to crops

gathering, etc.); there is a low level of organization among producers (presently there are only two authorized organizations of vegetable growers- greenhouse producers and Producers of sweet pepper); there are no trade agreements between producers and traders for the sales of final products;

- There are low prices for final products; low quality of vegetables; there are lack of people willing to work in agriculture and there are people who are poorly trained. These problems in combination with unfavourable climate conditions during the vegetation period for vegetables (hailstorms, heavy rains and floods, early autumn frosts, etc.) bring, on one hand, to reduce areas for vegetable growing, and on the other hand, we have lower volumes in production during the recent years.

1.2 Analysis of the Sector's Current Status

The adaptation to the new competitive environment is caused by the high social and economic price and the EU funds covered only a part of it. The benefits related to these has a limited influence due to the complex and clumsy procedures related to the provision of funds;

The field of vegetable growing was included in the common economic sphere of EU with no specific preparation. The strong competitive pressure represents a serious danger for the existence and development of the sector;

In order to overcome the specified problems and ensure sustainable development of the sector its necessary to provide well-trained people who know not only the traditional technologies used at present but also the principles of sustainable agriculture as well, especially related with keeping natural resources to next generations.

This imposes training of agricultural experts (in particular vegetable growers); include -synthesis of traditional practices (sowing turnover, mixed crops, etc.), the love to the land inherited from ancestors and modern scientific achievements from this perspective which will have a positive environmental effect over the agrarian ecosystems and the environment in general. From this perspective the presented study materials should be based on the principles of integration of different systems and methods of production; this will include sustainable management of fertilizing and irrigation; energy use associated with production; integrated control of pests with sustainable application in the farms. These principles should be presented in a special section entitled "Sustainable Growing of Vegetables" which will form the basic knowledge related to the topic; they should be incorporated in a suitable place in the respective sections for individual crops where developed of details with active participation of trained people.

1.3. Sustainable Management of Natural Resources in Relation to Vegetable Growing

The successful application of principles for sustainable development in the sector are possible after the following was realized:

- analysis of climate factors in Bulgaria;
- good knowledge of the genetic fund related to vegetable growing;
- introduction of power and water saving technologies;
- lower dependence on fossil fuels and greater sustainability with regard to climate change;
- consideration of social and economic aspects.

After analyzing climate factors the agro-technical activities should be synchronized by the following:

- Optimization of the period for sowing and transplanting – temperature, lighting duration, light intensity, rainfall pattern and intensity, winds, etc.
- There should be specific selection of suitable soil type for vegetable farms
- The natural resources should be considered – their volume, distribution and quality.

The modern power and water saving technologies are some of the most pressing innovations in the field of vegetable growing and they should be based on the following:

- Good knowledge of biological requirements of different vegetable crops;
- Energetic efficiency, quality and quantity of production;
- Protection of ground water resources;
- Limiting the greenhouse effects by biodegradable mulches, involvement of high techniques to reduce energy loss, modern lighting system, CO₂ enrichment, using bumblebees (*Bombus*), etc;
- Introduction of good agricultural practices – use of manure, rotation of crops, etc.

One of the ways for reduction of the anthropogenic pressure is the wider use of organic fertilizers. This is very much needed with regard to vegetable growing where the produce is consumed in its fresh form and processed form by people. The most important basis for biologically-friendly farming are the products obtained through composting, timing, etc. (12).

The main benefits of this activity are manifested by the following:

- Composting is a process by which the organic materials such as cut grass, leaves and food waste and vegetable peels are decomposed in a way which is controlled by people. The obtained product (compost) is used for return of nutrients to plants, benefit microorganisms and fertilizing the soil in farms.
- Composting allows limiting the volume of domestic waste which is daily directed to trash bins; at the same time we will have enhancement of soil characteristics in the farm; humus will be formed and the structure of the soil will be enhanced.

The humanity faces a great problem – continuous reduction of water resources. Therefore, water economy, especially with regard to vegetable growing has a great significance. The successful realization of such activity is based on:

- knowing biological requirements and environmental needs of plants; this is a basis for water saving.
- suitably selected and regulated systems, depending on grown crops.
- irrigation during the late afternoon when evaporation has its lowest intensity; moreover, will have water economy of 50% and the same water efficiency.
- mulching in order to have limited evaporation.
- collection of rain water in barrels, vessels, tanks or other units.
- grass which is allowed to grow a little bit higher is more resistant to drying and will bring water economy if compared with low-cut grass.
- Optimization of plant distance planting, will reduce water loss.

1.4. Sustainable Vegetables Farm

In relation to farming, different commercial products for protection of plants are used (herbicides, fungicides, insecticides, etc). This, however, brings permanent pollution of water, soil, final products and, respectively is danger to the people health.

The provision of enough vegetables with no use of such chemicals at present is not realistic. Despite this there are alternatives which can be used and the volumes can be reduced. This will reduce the risk for consumers and the environment. These are the following:

The traditional practices of vegetable growers from the past are extremely valuable asset nowadays. The farmers of the past applied agro-technical methods which, on one hand, were a tool to have compact use of land, and on the other hand, protected the crops from pests (1). The main principle here is that prophylactics of diseases is better than their treatment:

- The maintenance of suitable air conditions (often ventilation in the case of cabbage seedlings growing and more sparse planting in order to avoid spread of mildew (*Peronospora parasitica* (Pers.) Fr.)
- Late sowing of peas lead to reduce the percentage of seeds eaten by pests (*Bruchus pisi*).
- Suitable rotation of crops
- Fencing diseased sections Channel by canals, uprooting and burning of ill plants if decay was noticed on asparagus (*Rhizoctonia violacea* Tul. & C. Tul.)
- Planting onions, garlic, basil, lavender and other similar plants can repel some insects due to the volatile compounds they release (repellents, phytoncides, etc.)
- Use of windbreak plants.
- Growing crops which benefit each other's development through vegetation, etc.

The control of pests related to the sustainable farm growing is realized through a number of practices (Vogtmann, 1990; Panayotov, 2003; Karov et al.)

- Weeding of plants at a certain interval can bring avoidance and reduction of weeds development and spread.
- Use of mulching by organic and biodegradable chemicals.
- Use of traps for pests (pheromone and light traps, attractants, etc.)
- Treatment using plant chemicals (extracts) from blossoms, pine bark, some herbs or regular hoeing of the land.
- Use of parasites and antagonists; it is necessary to introduce integrated principles intergated pest management in relation to the protection of vegetable produce: multi-aspect environmental approach associated with the control of pests which is coordinated with pest bio-cycles and the way they communicate with another organisms and their competitors which exist in the environment; parasites and super parasites, antagonists, etc.

Donot not forget a the social and economic aspects which have their influence in relation as:

- Maintenance of historical and cultural inheritance related to the field.
- Maintenance of social and economic livelihood in rural areas as a tool for the preservation of population in these areas.

- Relationship between producers and consumers.
- The role of education and increase of awareness in relation to the encouragement of sustainable horticulture development.

Conclusion

Although there is no universal definition about what a sustainable system is, sustainable development and sustainable agriculture (including sustainable vegetable growing) the most simple should be defined as one which is directed toward the economic, environmental and social sphere. The applied technologies should meet the following conditions:

- They should be financially substantiated with sufficient profit which will maintain the interest toward such a production;
- They should be environmentally friendly, i.e. they should not affect negatively the existing bio-systems in the surrounding environment; they should try not only to protect this environment but also work for its maintenance and improvement;
- The direct producers should have a sufficient level of information, education and training in order to have proper realization of activities.

The objective reality – the membership of Bulgaria in the European Union; the constant extension of international economic, political and other links; the more intensive development of alternatives related to conventional agriculture, regardless of how it is called around the world (environmental, sustainable, biologically-friendly, etc.) put the vegetable growers in Bulgaria in a dynamic, competitive and complex environment. The natural resources and the prestige based on high quality are their important advantages; this in combination with better training and popularization in the field of sustainable vegetable growing realized in the educational institutions at different level is a basic prerequisite for future development.

The final goal should set is that each of the participants in the process (producers, professors and students) should to be harmoniously connected, so that they could most effectively realize their full potential in relation to the creation of agricultural units growing vegetables which are based and work according to the principles of sustainability as this will form a new farming culture.

References

- Bachvarov, St. 1986. Growing Vegetables in Bulgaria/Historic Notes, Zemizdat.
- Clugston R. 2011. Ethical framework for a sustainable world: Earth Charter Plus 10 conference and follow up. J. Educ. Sustain. Dev., 5, 173–176.
- De Leo J. 2012. Quality Education for Sustainable Development: An Educator Handbook for Integrating Values, Knowledge, Skills and Quality Features of EDUCATION for Sustainable Development in Schooling; UNESCO APNIEVE Australia Publishing: Adelaide, Australia.
- Hadzhieva, V. 2007. Sustainable Development of Agriculture in Bulgaria. Economic Alternatives, issue 5, pages 28-42.
- Karov, St., N. Panayotov, R. Andreev. 2008. Biologically-Friendly Production of Vegetables, Hr. Yancheva (editor); 2008. Biologically-Friendly Agriculture Handbook.

Lozano R., R.Lukman, F. J.Lozano, D. Huisinigh, W. Lambrechts. 2013. Declarations for sustainability in higher education: becoming better leaders, through addressing the university system. J. Clean. Prod., 48, 10-19. Ordinance No. 11 dated 6-Apr-2009 on the Conditions and Order for Application of Measure 214 “Agro-Environmental Payments” from the Program for Rural Development During the Period 2007-2013. SG issue 29/2009. National Plan for Development of Biologically-Friendly Agriculture in Bulgaria During the Period 2007–2013. MAF.

Panayotov N. 2000. Introduction to Biologically-Friendly Vegetable Growing. Agro-Environmental Centre, Plovdiv HAI.

Panayotov, N. 2003. Organic Vegetable Growing, Yancheva, Hr., I. Manolov (editor), 2003. Foundations of Organic Agriculture. Plovdiv HAI.

Stancheva, Y., S. Dimitrov, P. Todorova, V. Todorova, S. Bencheva, I. Dimitrova, V. Piralkov, V. Taseva, M. Yordanova, K. Malinova, S. Lukipudis, Z. Shindarska, 2008. Biologically-Friendly Agriculture Handbook for Entrepreneurs. UF – Avangard Prima, Sofia.

Vogtmann, H. 1990. Environmental Farming. Environmental Agriculture Foundation.

Weingerl, V., N. Shaban, I. Kadhum. 2015. Innovation in the teaching of Sustainable Development in Life Sciences in Europe Erasmus Networks project N° 177267-LLP-1-2010-1-FR-ERASMUS-ENWA. INNOVATIVE PRACTICES COMPENDIUM. 2nd edition
www.isle-project.eu. ISBN: 978-961-6704-49-6

<https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf>.

BULGARIAN JOURNAL OF SOIL SCIENCE®

INSTRUCTIONS FOR AUTHORS

Manuscript Submission

Submission of the manuscripts implies that they have not been published before nor are currently submitted or considered for publication in any other journals, which should be declared in **cover letter** by the authors.

The manuscripts must be submitted in electronic version to the Editorial e-mail address: Journal@bsss.bg

Language

Manuscripts should be written in clear and grammatically correct English. British or American English spelling and terminology must be used. If English is not your native language we strongly recommend that the text of your paper be checked by a native speaker or a professional science editor before submission.

Types of Manuscripts

Bulgarian Journal of Soil Science publishes four categories of papers and the authors must indicate the category of their submission in the cover letter:

- Regular research papers must be based on results of original research. They will normally have a maximum length of 20 pages including tables, illustrations and references (on separate sheets).
- Research notes and short communications should be concise, focused on new results and data. They will be no longer than 5 pages, including the tables and figures.
- Review papers (invited or consulted with the Editor prior to preparation of the manuscript) with maximum length of 25-30 pages (according to the importance of the material).
- Book reviews and critical comments on articles and events up to 3 printed pages.

General presentation of the manuscripts

The manuscripts should be double-spaced (1800 characters per page), without section breaks, on A4 (210 x 297 mm) paper size, with margins of at least 2.5 cm at the top, bottom and sides. Lines should be numbered in the margins with a continuous numbering from the start of the manuscript. All pages should be numbered consecutively in the bottom, right-hand corner. The manuscript should be arranged as follows:

Title Page

The title page should include:

- Full and short (running head) titles of the manuscript. The full manuscript title must be limited up to 20 words, and the short title – up to 7 words in small capitals;

-
- The name(s) of the author(s) in small capitals;
 - The affiliate institutions(s) and address(es) of the author(s);
 - The e-mail address of the corresponding author.

Abstract

Please provide an abstract up to 1500 characters that includes a clear statement of the research objectives, a short overview of the methods used, the most important results and a conclusion. No references and abbreviations should be used in the Abstract.

Key words

Please provide 4 to 6 key words, which can be used for indexing purposes. Avoid overlaps with the title.

Order of sections

The standard order of sections should be: Introduction, Material and Methods, Results, Discussion (or Results and Discussion), Conclusion, Acknowledgements, and References.

The content of the manuscript should be structured in accordance with the following criteria

1. **Introduction.** It should present a general framework of the topic in justifying why the authors have performed the study. State-of- art on the research topic has to be presented briefly to derive the novelty of the study and to show its relation to the preceding works. A distinct paragraph at the end of this chapter should state the objectives of the work.

2. **Materials and Methods.** This chapter should present detailed information of the place of research, as well as of data collection and analyses. Sufficient detail should be provided to allow the work to be reproduced. Methods already published should not be described in text but rather indicated by a reference.

3. **Results and Discussion.** It is recommended that results of the research are presented in a clear and concise manner. Information in charts, tables, photos or graphics should not be repeated in the text. This chapter should not contain a comparative assessment with similar papers or information on data analyses procedures. Also to make a comparative analysis between the results of the current research and those already published. This should not reiterate the results of the work but rather explore their significance. Published literature which is relevant to results and aim of the current study should only be cited.

4. **Conclusion.** This chapter or subsection of the discussion chapter should be concise and derived from the results of the research and the discussion presented. General statements are not allowed.

Scientific style

Please always use internationally accepted signs and symbols for units, SI units. Genus and species names should be in italics.

Text Formatting

- Use a normal, plain font (e.g. 12-point Times New Roman) for text and line spacing at 1.15.
- Use italics for emphasis.
- Use the automatic page numbering function to number the pages.

-
- Do not use field functions.
 - Use the equation editor for equations.
 - Save your file in *.docx format.
 - Headings. Please use no more than three levels of displayed headings.
 - Abbreviations should be defined at first mention and used consistently thereafter.
 - Footnotes can be used to give additional information. Footnotes to the text are numbered consecutively; those to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data). Footnotes to the title or the authors of the article are not given reference symbols.
 - Acknowledgments (10-point plain font) of people, grants, funds, etc. should be placed in a separate section before the reference list. The names of funding organizations should be written in full.

Tables

The tables should always be cited in text in consecutive numerical order and must be numbered using Arabic numerals. Each table must be as simple as possible, double-spaced, of size no bigger than 12 x 18 cm. For each table, please supply a table caption (title) describing its content. Footnotes to tables should be indicated by superscript lower-case letters or asterisks and included beneath the table body.

Illustrations

All illustrations, including charts and photos, must be labelled as Figures. They must be numbered consecutively and should be provided with an explanatory legend on a separate sheet entitled 'Figure captions'. They should conform to the size of the typed area (12 x 18 cm) which is the maximum size for the illustrations. Magnification should be shown by scale bars. Files in XLS, TIF, JPG and WMF formats are accepted. After the paper is accepted the editors will ask for figures in JPG or TIF format with 300 Dpi. Colour illustrations are accepted without fees for electronic publications. The editors reserve the right to decide what figures are justified and can be published in RGB colour (other figures will be removed or published in black and white).

References

Citation

Cite references in the text by name and year in parentheses as follows: Bauer (1932) or Bauer, Smith (1951) or (Bauer, 1930; Smith and Albert, 1931, 1935; Bauer et al., 1965) or Steffanic et al. (1951), up to two authors, give the names; for more than two authors, give the name of the first author followed by 'et al.'. Check each reference with the original article and refer to it in the text. All authors of a paper should be cited in the list of references. References 'in press' shall only be cited when they have been accepted for publication.

Reference list

References should be arranged first alphabetically and then further sorted chronologically if necessary. More than one reference from the same author(s) in the same year must be identified by the letters 'a', 'b', 'c', etc., placed after the year of publication. In case of papers written in other than Latin letters, if there is an English (or German, French) title in the summary,

it may be used. If there is not such a summary, the author's name must be transcribed (using British English transcription) and the title of the paper must be translated into English. This should be noted in round brackets at the end of the paragraph, for instance: (In Bulgarian).

Some examples for references to journal publications, books, chapters in edited books and electronic publications or databases:

- Atanassova, I., S. Doerr, 2010. Organic compounds of different extractability in total solvent extracts from soils of contrasting water repellency. *European Journal of Soil Science*, 61, 298-313.
- Schwesig, D., A. Göttlein, L. Haumaier, R. Blasek, G. Ilgen. 2013. *International Journal of Environmental and Analytical Chemistry*. URL: <http://dx.doi.org/10.1080/03067319908032668>.
- Calderón, H. W. 1982. The content and composition of humus in arid alluvial soil of Peru. *Soil Science, Academy of Sciences of USSR, Moscow*, 8, 53-59. (in Russian)
- Sparks, D. L. 2002. *Environmental Soil Chemistry*, 2nd Edition, Academic Press, San Diego, CA
- Sparks, D. L., Huang, P.M. 1985. The physical chemistry of soil potassium. p. 201-276.
- In R.E. Munson (ed.) *Potassium in agriculture*. Soil Science Society of America, Madison, WI.
- Noyes, J. S. 2013. *Universal Chalcidoidea Database*. World Wide Web electronic publication. Last update 29 August 2013. URL: <http://www.nhm.ac.uk/chalcidoids>.

General Peer-Review Process

The submitted manuscript should not have been previously published and must not be currently considered for publication in another journal.

Violations of these rules will strictly result in an immediate rejection of the submitted manuscript.

Submission of Manuscripts

All manuscripts submitted for publication will be peer-reviewed by anonymous referees.

Submitted manuscripts will undergo a Plagiarism Check in the Editorial Office.

Papers will be registered with a date of submission and a date of acceptance for publication. If papers sent for revision are not returned to the editorial office within five weeks, these shall be registered with a new date of submission.

The corresponding author shall be notified in case a paper is rejected not later than two weeks after the decision had been taken.

The authors are responsible for the opinions expressed by them and for the plausibility of their data.

The authors must fill the "Copyright Release Form".

The Journal is free, web based and open access. Only printed hard copy is paid with a price of 50 Euro, if it is wanted.

